

ENCYCLOPEDIA OF CHEMISTRY.

THE
ENCYCLOPEDIA OF CHEMISTRY,

Practical and Theoretical:

EMBRACING

ITS APPLICATION TO THE ARTS,
METALLURGY, MINERALOGY, GEOLOGY, MEDICINE,
AND PHARMACY.

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PREFACE.

THE Encyclopedia of Chemistry, now offered to the public, is designed to present a view of the whole science, with constant reference to its various applications to manufactures, medicine, pharmacy, and mineralogy. The minuter details of these applications are not presented unless the subject be one of those more particularly termed *Chemical Manufactures*. The importance of *Metallurgy*, in the United States, and the too prevalent ignorance of its principles, induced me to enter more fully into metallurgic processes, and their theoretic explanation. The department of *Mineralogy* offers a concise, yet sufficiently full description of species and varieties, together with their chemical behavior and composition, the latter expressed by a formula, where it has been determined, and often by per-centage composition, where it is considered of sufficient importance. *Chemical Geology* has received some share of attention, as far as positive knowledge would warrant. The few masterly essays on this subject were not sufficiently general to allow of their introduction, but it is to be hoped that in a few years the importance of the subject will attract the labors of more chemists, and produce valuable results. Vegetable and animal *Physiology*, *Medicine*, and *Pharmacy*, in their chemical bearings, have not been neglected, but have not received such attention as the author desired, as he considered them as yet in embryo, and too overladen with theories to be introduced, in their minuter details, into a practical work like the present.

When the present work was commenced, it was the publisher's desire, and my intention, to base it upon Ure's Dictionary of Chemistry, modifying it in such a manner as to adapt it to the present state of the science, but a cursory glance at it forced me to the conclusion that the science had so entirely changed its features as to render that work of no avail: nothing has in consequence been taken from it. The works from which the matter is chiefly drawn, are those of Berzelius, Gmelin, Mitscherlich, Rose, Liebig, Schubarth, in the German; Dumas, Berthier, Pelouze and Fremy, Millon, Regnault, in the French; Graham, Liebig, Turner, and others, in English. The journals chiefly made use of, were Poggendorf's *Annalen der Physik*, &c., *Annalen der Chemie und Pharm.*, *Journal für prakt. Chemie*, Berzelius's *Jahrbuch*, *Comptes Rendus*, *American Journal of Science*, *Journal of the*

Franklin Institute, and especially the Chemical Gazette, which contains excellent abstracts of foreign papers. The dictionaries resorted to, were Liebig, Poggendorf, and Wöhler's, Ure's Dictionary of Manufactures, Dictionnaire des Arts, and Dictionnaire de l'Industrie. In Mineralogy, Dana's admirable treatise has been freely used, and the author would call attention to this work, as one of the best works on Mineralogy, not excepting German or French treatises. Besides this work, Berzelius's Essay on the Blowpipe, and Rammelsberg's Handwörterbuch des Chem. Theils der Mineralogie, have supplied the applications of Chemistry to this department of natural science.

The sources have been generally too many in the same articles to allow of space to acknowledge the authority.

M. H. BOYÈ, M. D., was associated with the author in the first part of the work, and the subjects from his pen are, Albumen, Alcohol, Alcoholometry, Analysis, Atmosphere, Balance, Beer, Bile, Blood, Compound Blowpipe, Bone, Bone-black, Brain, and a few smaller articles, between pages 79 and 372.

Mr. CAMPBELL MORFIT was associated with the author in the last half of the work. The larger articles written by him are, Cochineal, Cotton, Essential Oils, Fats, Gelatin, Madder, Oils, Protein, Quinin, Salicyl, Starch, Stearin, Sugar, Tartaric Acid, Turpentine, Thermometer, Varnish, Water, Wax, Wheat, and Wood. Besides these, he penned a large proportion of the smaller articles, from page 465 to the end.

Professor R. S. McCULLOH favored the author with the admirable article on Electricity, which it is desirable the public should possess in a separate publication. He also furnished the article Hydrometer.

The remainder of the work is due to the author. That it is not perfect, he is ready to admit; nor is it indeed practicable to produce a complete work on Chemistry, in the present changing state of the science. As an apology for many imperfections, which the advanced chemist will detect, and for delay in publication, let it not be forgotten that the work has rather been the production of leisure hours, amid the unceasing engagements of his profession, Instruction in Practical Chemistry. The author's own observations and experience, collected during many years of chemical study and practice, are interwoven throughout, usually without drawing attention to them. His principal object has been the dissemination of sound practical knowledge through the United States, whereby the Chemical Arts, which are most characteristic of civilized life, may be established and conducted on rational principles.

JAMES C. BOOTH.

Philadelphia, February, 1850.

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A.

ABIETINE. *Chem.* A crystallisable resin discovered by Caillot, in Strasburg turpentine, of which it constitutes about 11 per ct., and believed by him to be peculiar to the genus *Abies* of Decandolle.

ABRAZITE. *Min.* See **ZEAGONITE**.

ABSINTHINE. *Chem.* The bitter principle of the wormwood (*Artemisia absinthium*). It is prepared by a succession of operations almost identical with those described for obtaining senegine. See **SENEGINE**. When completely pure, it is white and crystalline; its taste is intensely bitter; it fuses at a high temperature, and closely resembles a resin; its best solvent is alcohol. It possesses the characters of a weak acid, being much more soluble in alkaline liquors than in pure water, and being precipitated from such solutions on the addition of an acid. With oil of vitriol, it is coloured first yellow, and then dark reddish purple.

ABSOLUTE ALCOHOL. *Chem.* A term applied to pure alcohol, absolutely free from water, or containing 98 to 99 per ct. of anhydrous alcohol. See **ALCOHOL**.

ABSORBENT. *Chem.* A substance possessing the power of receiving liquids or gaseous bodies into itself, with or without chemical action. Thus charcoal absorbs gaseous matter; dry clay is an absorbent of fats and oils; and boiled plaster and quicklime take up water. The last is a case of chemical combination. See **ABSORPTION**.

ABSORPTION. *Physics, Chem.* A term variously employed to denote the property and action of certain solids and liquids to take up gases and vapors. Quicklime absorbs carbonic acid, with which it forms a definite chemical compound, the carbonate of lime, and then absorption ceases; now if we take two equal weights of marble (crystalline carbonate of lime), the one solid and the other powdered, the latter will be found to weigh heavier from the abstraction of moisture from the air; but this instance of absorption is very different from the preceding, since it is not definite in quantity, may vary according to the pressure and temperature of the air, the fineness of the powder, &c., while in the former case an exact amount is absorbed, within a very wide range of pressure and temperature. Moreover, the moisture may be expelled from the powdered marble by a very slight increase of tempera-

ture, while its carbonic acid requires a white heat for its expulsion. The latter holds its carbonic acid in obedience to chemical attraction, while the powder absorbs moisture apparently in accordance with another kind of attraction, which we shall denominate *absorption*. It would not be difficult to determine the limits of this mechanical absorption, if we could exactly define what a chemical compound is; but the latter is frequently so loose in its nature, existing only in solution, decomposable by such slight differences of temperature, that we must often be in doubt whether to regard it as a mixture or definite compound. We may in general define it as the power possessed by liquids and solids, the latter either porous or pulverulent, to receive vapors and gases into their own mass, without materially altering their principal and essential characters. The following essay on this subject is taken chiefly from an excellent article by Pogendorf in the *Wörterbuch der Chemie*.

I. ABSORPTION OF GASES AND VAPORS BY SOLID BODIES.

All solids, as soon as they acquire the requisite degree of porosity or division, exhibit the faculty of absorbing gases, but few possess it in a striking degree, and among these charcoal has always held a prominent position, and was for a long time regarded as alone possessed of it. Scheele and Fontana discovered this power in charcoal, independently of each other, about 1777, since which period it has been more or less investigated by Priestley, Saluzzo, Morveau, Morozzo, Delametherie, Rouppe and Van Noorden, Parrot and Grindel, Van Mons, Brugnatelli, and Vogel. But the researches of Theodore de Saussure are the most extensive and appear to be most carefully made, and we shall draw chiefly from them.

Absorption by Charcoal.—The amount of absorption, i. e. the rapidity and quantity of the same, appears to depend on, 1st, the dryness and freedom from air of the coal; 2d, its degree of density or porosity; 3d, the pressure of the gas to be absorbed; 4th, the temperature; 5th, the nature of the gas; and 6th, on its purity. These conditions hold good of the other solid bodies.

1. *Dryness and freedom from air of the coal.*—The absorbent power of coal can only be determined when it is wholly free from gases, vapors, or liquids. Aqueous vapor in par

ticular is readily absorbed. Charcoal lying in the open air for a considerable time increases 10 to 20 per ct. in weight, the greater part of which is the vapor of water. Boxwood coal, which in a dry and air-free state absorbed 35 times its volume of carbonic acid gas, after moistening with water, absorbed only 15 times its volume, and while the former amount was taken up in 24 hours, the latter smaller quantity required 14 days. This phenomenon is connected with the fact that water expels the greater portion of a gas absorbed. 1 vol. coal, which had taken up 33 vols. carbonic acid gas, lost 17 vols. by moistening it with water.

Saussure and Fontana attained this dry and vacuous state of coal by igniting it strongly, and bringing it rapidly and while still hot into mercury, and, immediately on cooling, passing it into the gas to be absorbed in a tube over mercury. The amount of mercury absorbed is so slight that the coal floats on water.

2. *Density and Porosity.*—The more dense a coal is, the smaller its pores, the stronger is its power of absorption within certain limits. Thus,

One volume of	Spec. Grav.	
Cork charcoal,	0.1	absorbed very little air.
Pine “	0.4	“ 4.5 vols. “
Boxwood “	0.6	“ 7.5 “ “
Stoncoal from } Ruffiberg, }	1.326	“ 10.5 “ “

Still denser coals, such as graphite of spec. grav. 2.17, or gas-retort-carbon, absorb nothing, from the smallness or absence of pores.

On the other hand, the powdered charcoals lose a portion of their absorbent power from the greater size of their interstitial spaces. Boxwood coal 4.92 cubic centimeters in size absorbed 7.5 times its vol. of air, while when reduced to an impalpable powder it only took up 3 times its volume of the same.

3. *External pressure* on the gas has great influence on absorption. The greater the pressure, the more is absorbed, and vice versa. Charcoal takes up a greater volume of an expanded gas, but a greater weight of a condensed gas. Diminution in pressure, therefore, as under the receiver of an air-pump, extracts the greater part, but not the whole of an absorbed gas.

4. The higher the *temperature*, the less gas is absorbed; for the greater part is removed by warming, and the whole by ignition. Diminution of temperature increases absorption, by opposing the elasticity of the gas.

5. *Nature of the Gas.*—Saussure found that in 24 to 36 hours one vol. boxwood coal absorbed of the following gases:

Ammonia	90 vols.
Chlorohydric acid	85 “
Sulphurous acid	65 “
Sulphuretted hydrogen	81* “
Nitrous oxide	40 “
Carbonic acid	35 “
Carbonic oxide	9.42 “
Oxygen	9.25 “
Nitrogen	7.5 “
Hydrogen	1.75 “

* Dr. C. Henry. Saussure's sulphuretted hydrogen was probably impure.

By comparing this table with that of the liquefaction of gases (see *GASES*), we find in general that those most easily liquefied are absorbed in greater quantity. For the same reason vapors are absorbed in such large quantities.

It is hence evident that the 10 to 20 per ct. increase in weight of charcoal in the open air arises chiefly from aqueous vapor. Of other vapors, we know that those having odor are rendered inodorous. Bottles filled by Döbereiner with tobacco smoke, asafœtida, &c. were rendered inodorous in from 1 to 3 hours. This subject will receive farther elucidation under *CHARCOAL*.

6. *Purity of the Gases.*—When gases and vapors are mingled, the absorption seems to depend on a kind of elective affinity. The following are the results of Saussure. *a.* Coal, fully charged with one gas and brought into another, loses part of the first to receive a portion of the second. If the former be more condensible, the volume of gas around the coal is increased by the exchange, and cold is produced; in the opposite case heat is generated. Hence charcoal in the air absorbs more oxygen than nitrogen (see the above table). *b.* The larger the quantity of the expelling gas, the more rapidly is the other expelled. *c.* A mixture of two gases is often more largely absorbed than either of the two separately. Thus the presence of oxygen in coal favors the absorption of hydrogen, the presence of carbonic acid or nitrogen that of oxygen, &c., but the presence of nitrogen does not favor the condensation of carbonic acid. *d.* Notwithstanding this increased absorption, there appears to be no chemical combination between the absorbed gases, at least Saussure's experiments lead to such conclusion. On the other hand, Thénard found that charcoal acted on a mixture of sulphuretted hydrogen and oxygen or atmospheric air, like platinum sponge on oxy-hydrogen; water was formed and sulphur deposited.

The following circumstances should also be observed in reference to absorption. 1. That in consequence of the condensation of the gas, *heat is developed*. The charcoal reduced to powder by bronze-balls, in revolving drums in the gunpowder manufacture, takes $\frac{1}{3}$ the space of the same when in pieces of 15 or 16 centimeters length, and absorbs air so rapidly as often to inflame. But this depends on the manner of charring, on the time elapsing between the charring and powdering, and lastly on the quantity of coal. 2. *Rapidity of absorption* varies with the nature of the gas, with the dryness and porosity of the coal, with the degree of charring, and with the relative dimensions of the coal. 3. *Alteration of gases.* Most gases are not changed by absorption, except oxygen and nitric oxide. The latter is decomposed, giving rise to carbonic acid and nitrogen. The oxygen appears to combine with a portion of carbon to carbonic acid, but the operation is extremely slow. This absorption and change bears reference to the employment of charcoal in the soil, although Liebig is of opinion that “it may remain in the soil unchanged for centuries.” (See *Johnson's Dictionary of Agriculture*, art. *Charcoal*.) Its change may be referred to another cause than that of absorbed oxygen alone. 4. It is doubt-

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ful whether the charcoal would suffer change in its chemical or physical properties if the absorbed gas could be expelled without heating.

Absorption by other solid Bodies than Charcoal.—The experiments made with other porous bodies are not so satisfactory as with charcoal.

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We find 1st, that all porous solids are endowed with a greater or less power of absorption; 2d, that those in general are most absorbed which exhibit the same power with charcoal. The following table of Saussure shows the amounts of absorption at 59° F.

Names of the gases absorbed.	Volumes of gases absorbed by one volume of									
	Charcoal.	Meerschaum.	Adhesive slate.	Ligniform Asbestus.	Hydrophane.	Gypsum.	Hazelwood.	Pinewood.	Linen Thread.	Wool.
Ammonia.....	90.0	15.0	113.0	12.75	64.0		100.0		68.0	
Chlorohydric acid....	85.0				17.0					
Sulphurous acid.....	65.0				7.37					
Sulphuretted hydrogen	81.0	11.7								
Nitrous oxide.....	40.0	3.75								
Carbonic acid.....	35.0	5.26	2.0	1.7	1.0	0.43	1.1	1.1	0.62	1.7
Carbonic oxide.....	9.42	1.17	0.55	0.58			0.58		0.35	0.3
Oxygen.....	9.25	1.49	0.7	0.47	0.6	0.58	0.47	0.5	0.35	0.43
Nitrogen.....	7.5	1.6	0.7	0.47	0.6	0.53	0.21	0.21	0.33	0.24
Hydrogen.....	1.75	0.44	0.48	0.31	0.4	0.50	0.58	0.75	0.35	0.3

Metals in a state of extremely fine division exhibit absorbent powers not inferior to charcoal. Powdered iron obtained by reducing the oxide by hydrogen at a gentle heat, retains, according to Magnus, a considerable quantity of hydrogen, which may have an influence on its pyrophoric properties. Platinum sponge does not absorb oxygen or nitrogen, according to W. C. Henry's experiments, nor ammonia, chlorohydric acid nor sulphuretted hydrogen gases according to Thénard, but platinum-black acts powerfully. (See PLATINUM-BLACK for its preparation.) Liebig holds it to be extremely comminuted platinum. When pure and dried over sulphuric acid under the air-pump, it absorbs air so rapidly as to become ignited. When pure it absorbs 250 times its volume of oxygen, and thus charged it takes up hydrogen, ammonia, &c., vapor of alcohol in very large quantity, becomes heated and changes the alcohol into vinegar. We might attribute the property of this body to ignite oxyhydrogen to its absorbent power, if Faraday had not shown that solid platinum with perfectly smooth surfaces has the same power, although it possesses no action towards these two gases separately.

The absorption of moisture by solids will be found under the art. **HYGROMETRY.**

II. ABSORPTION BY LIQUIDS.

The absorption of gases and vapors by liquids depends on circumstances similar to those given under absorption by solids. We find the absorption influenced 1st, by the nature and purity of the absorbing liquid; 2d, by the nature and purity of the gas; 3d, by pressure; and 4th, by temperature.

1. A liquid will of course absorb more gas, the less of the same gas it already contains. The following table, by Saussure, exhibits the influence of different liquids on the same gas.

Absorption of Carbonic Acid Gas by different Liquids, at 64.4° Fahr.

One volume	Sp. Gr.	Volumes of gas absorbed.
Alcohol.....	0.803	2.60
Ether.....	0.727	2.17
Spirit of wine....	0.84	1.87
Spirit of turpentine	0.86	1.66
Linseed oil.....	0.94	1.56
Water.....	1.00	1.06
Solution of		
Gum.....	1.092	0.75
Sugar.....	1.104	0.72
Alum.....	1.047	0.70
Sulphuric acid....	1.84	0.45
Chloride of sodium	1.212	0.329
Chloride of calcium	1.402	0.261

It is evident from this table that the spec. grav. exercises much influence on absorption, for all the above liquids lighter than water surpass it in absorbent power; those heavier fall below it. But although absorption appears in a general way to be inversely as the spec. grav., yet a comparison of alcohol and ether, sugar and alum, &c., show that an exact law cannot be laid down. The relative absorption is just as irregular where other gases are employed as with carbonic acid. There is certain attraction between the fluid and the gas which influences absorption besides density.

2. *Nature and Purity of the Gases.*—This is clearly shown by the following table:

At 64.4° there is absorbed of	1 vol. air free water.	1 vol. air free Alcohol, Sp. Gr. 0.84.
Sulphurous acid gas..	43.78	115.77
Sulphuretted hydrogen	2.53	6.06
Carbonic acid.....	1.06	1.86
Nitrous oxide.....	0.76	1.53
Oxygen.....	0.65	0.1625
Hydrogen.....	0.046	0.051

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The above table shows that, in general, the most condensable gases are most absorbable. By comparing it with the tables for absorption by solids, it is evident that the latter, particularly charcoal and meerschau, possess a far greater absorbent power than water or alcohol, or, indeed, than any liquid. Ammonia and chlorohydric acid gases are exceptions to this rule, for water, at 50° Fahr. absorbs 480 times its volume of the latter and 670 times its volume of ammoniacal gas.

3. *Influence of Pressure.*—Henry's experiments in 1803 led to the conclusion that the volume of each gas absorbed at the same temperature by water, remains the same, whatever may be the pressure. This may be generalized, by saying, that the volume of a gas absorbed by a liquid is the same under any pressure, the temperature being constant; and from this we draw the conclusion, that the weight of gas absorbed by a liquid is directly proportional to the pressure on the gas, the temperature being constant. Chlorohydric and a few other gases absorbable in great quantity are exceptions to this law.

Suppose we have 100 cubic centimeters of water, with a sufficient quantity of carbonic acid enclosed in a vessel, at 64·4°F., which is connected with a forcing pump. After some time the water will have taken up 106 cub. centim. of the gas (see the above table), which at 30 In. B. weigh 196·6 grammes. Now by doubling and trebling the pressure, the same bulk will be absorbed, but it will be in the former case 393·2 and in the latter 589·8 grammes or double and treble the weight. On this action depends the preparation of artificial MINERAL WATERS, which see.

The reverse takes place when the pressure is diminished. If a liquid be charged at ordinary atmospheric pressure and this be lowered, a portion of gas escapes until the same volume remains in the liquid as it is capable of absorbing; or if it had been charged under high pressure, the excess escapes when the pressure is removed, a phenomenon constantly occurring with beers, mineral waters, and other effervescing drinks.

4. *Influence of Temperature.*—This point has not been sufficiently determined in detail. It seems to follow from Dalton's experiments that "the volume of a less absorbable gas, which

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is taken up by one and the same weight of liquid under uniform pressure, remains the same at all temperatures;" but we have not sufficiently precise experiments by others to determine this point.

Boiling.—Dalton's law only holds good of a liquid in a closed vessel, for if it be opened, the gas above the liquid passes into the air, although it may have the same pressure, and the absorbed gas gradually follows. The higher the temperature, the more rapidly does it escape, until, at the boiling point, it has reached its maximum.

Boiling, therefore, acts like the vacuum of an air-pump, but more rapidly, and yet the whole of the gas cannot be expelled even by long-continued boiling, according to Saussure, Priestley, &c., and it appears finally to pass off as a whole with the vapor of the liquid, even with the less absorbable gases, as we know that it does with hydrochloric acid gas, &c. It has not, however, been ascertained whether the introduction of an angular body, such as pieces of platinum or osmium iridium, might not wholly expel air, carbonic acid, and similar gases, for such bodies greatly assist ebullition.

The more absorbable gases act, in general, under different temperatures, like those less so, but in some respects they vary. Ammonia is absorbed in greater quantity in the cold than at increased temperatures. A watery solution of ammonia boils at a higher temperature the less ammonia it contains, as shown by the following table of Dalton, where the content of gas is given in pr. ct. by weight.

Pr. ct. of Ammonia.	Boiling point.	Pr. ct. of Ammonia.	Boiling point.
35·3	—24·8	15·1	+122·0°
29·9	+150·0	10·5	145·4°
24·7	73·4	6·2	174·2°
19·8	98·6	2·0	197·6°

Hydrochloric acid acts differently. That solution containing 19 pr. ct. by weight of the dry gas has the highest boiling point 230°, and this point remains unchanged by continued boiling, since the solution then evaporates as a whole. The following table, by Dalton, shows the peculiarity of liquid hydrochloric acid, although his numbers are not exactly correct. The gas is expressed in pr. ct. by weight of the solution.

HCl acid.	Boiling point.	HCl acid.	Boiling point.	HCl acid.	Boiling point.
34·1	+120·2	23·3	+217·4	11·2	+224·6
31·2	149·0	21·8	221·0	8·65	221·0
28·8	168·8	20·6	228·2	6·94	219·2
26·6	188·6	16·1	231·8	3·53	215·6
24·9	212·0	13·2	228·2	1·81	213·8

By observing the table we find that "water at the pressure of the atmosphere has two points of saturation between 212° and 231·8°." The above shows that it is not external pressure alone that retains the gas at 230°, and it is difficult to account for it by affinity, for the gas and water are as 1 atom to 17½ atoms. At present we cannot explain it.

Mitscherlich found a similar result with nitric acid, viz. that a solution containing 60 pr. ct. of the dry acid has the highest boiling point, which is at 253·4°. Sömmering and v. Yelin found that alcohol has its lowest instead of its highest boiling point, as shown by the following table of v. Yelin:—

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Pr. ct. Alcohol.	Boiling point.	Pr. ct. Alcohol.	Boiling point.	Pr. ct. Alcohol.	Boiling point.
100	+168·41°	97	+168·08°	95	+168·33°
99	168·17°	96	168·23°	94	168·33°
98	168·08°				

On the evaporation of alcohol and water. See DIFFUSION.

Freezing the Liquid.—We have seen that absorption generally increases with a diminution of temperature, but it usually extends only to the freezing point, where, in all probability, the absorbability of every gas suffers a sudden change, even if it be a slight one. By cooling down water charged with air, we observe at the moment of freezing the greater part of it suddenly expelled, and only a few small bubbles remaining enclosed mechanically in it. By repeated freezing, it is probable that every particle of air might be expelled, for Carradori found that a fish died instantly in such water.

The more absorbable gases seem not to be expelled by freezing the liquid, at least not in such quantity as air, &c. The watery solution of sulphurous acid solidifies a little below 32° F., that of hydrochloric acid below the freezing point of mercury, without apparently losing gas. They may possibly form chemical compounds with water, as Faraday has shown that chlorine water, by freezing at about 32°, separates into hydrated chlorine and ice, free from chlorine. Ice has not lost its absorbent power for these gases, for it melts in the heat developed by their rapid absorption.

There is a singular kind of absorption and expulsion of gas by a fluid with a high freezing point, viz. melted silver, which is frequently absorbed in the dry Assar, which see. It absorbs oxygen in the liquid state, without losing its metallic lustre, and on cooling to congelation, suddenly gives it off, giving, after the moment of *brightening*, a jagged appearance to the solid button of silver. This effect has been attributed to crystallisation, but Gay-Lussac has confirmed the experiments of Lucas on this point.

There are other circumstances influencing absorption. Thus it is probable that a gas is more largely absorbed in a smooth vessel, as glass, than in one of a rough or metallic surface. Time is another circumstance, according to the experiments of De Marty, but it is possible that the increased absorption of a gas after the lapse of time may give rise to chemical combinations in the liquid. Rapidity of absorption is dependent, in general, on the same circumstances which influence the amount of absorption.

Phenomena accompanying Absorption.—The development of *heat* by the absorption of a gas, is the most striking circumstance. It is generally greater in proportion to the amount and rapidity of absorption; hence the temperature of water saturated with hydrochloric acid rises to 212°, while, with carbonic acid, it does not increase by one degree of Fahrenheit's scale. The condensation of the gas is probably the principal, if not the only cause of the evolution of heat.

The volume of the absorbing liquid is altered by its receiving a gas, and it appears always

enlarged. The density of the liquid is increased by the absorption of some and diminished by others; thus the aqueous solutions of ammonia are specifically lighter, those of hydrochloric acid heavier than water.

Theory of Absorption.—The phenomena are generally referred either to capillary or chemical attraction, or to both as by Dr. Dalton; but our experience on this subject is too limited to admit of establishing a satisfactory generalisation, since it may be said that Henry's law, above given, is the only one we possess, and that will not admit of universal application. A majority of philosophers hold that liquids are active and not passive in absorption, and that they exert upon the particles of gas an affinity varying according to their chemical character. It may then be stated as the best general conclusion warranted by the present state of our knowledge, that the same forces are exerted in the absorption of gases which we regard as the cause of chemical combination; but that, in those cases of what seems to be more a mechanical absorption, these forces are too feeble to overcome the elasticity or tension of the gases, and that therefore an external pressure (such as arises from the elasticity of the unabsorbed gas) is requisite to produce combination, the amount depending chiefly on the pressure.

ABSORPTION. Tech. The preceding article may admit of various applications in the arts, and should not therefore be regarded as merely speculative physical science. The tendency of charcoal to absorb gaseous bodies and liquids has already received practical attention in various arts, but there are undoubtedly many others which might derive benefit from a closer study of all the phenomena attending it. Its importance in the powder-manufacture has already been alluded to, and it is highly probable that loss of life and property might be obviated by a closer attention to the principles or rather facts, as far as they are developed. The peculiar property of platinum-black has also been applied to the production of vinegar, although not with sufficient economy; and other useful combinations might be effected by it.

The study of the absorption of gases by liquids may be usefully pursued in the impregnation of water by carbonic acid, in the manufacture of liquid acids, ammonia, and other chemical solutions, and in the distillation of liquids generally. The neglect of principles most generally leads to heavy losses in practice.

ACANTICONITE. Min. A variety of Epidote from Arendal in Sweden. See **EPIDOTE**, **Pistacite**.

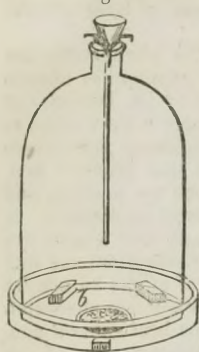
ACECHLORULE. Chem. A compound radical, consisting of chlorine and carbon, C₄Cl₃, of which chloral is the hydrated oxide. Chloral is composed of C₄HCl₃O₂ which may thus be separated when viewed as a compound

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of acechlorure $C_4Cl_3O + HO$. See **CHLORAL** and the action of chlorine on **ALCOHOL** and the **ETHERS**.

ACETAL. *Chem.* Discovered by Döbereiner who named it oxygen-ether. To prepare it, place several watch-glasses, containing thin layers of platinum-black slightly moistened, near the surface of alcohol contained in a dish

Fig. 1.

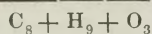
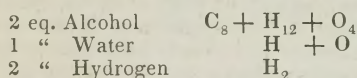


as in fig. 1. *b.* Pass a 12 inch high bell-glass over it, of a diameter less than that of the dish, with an opening above partly closed, to allow the gradual entrance of a little air, or containing a funnel-tube, as in the fig., and place the whole in a moderately warm situation for several weeks or months. The liquid condensing on the sides of the glass, and flowing into the dish contains acetal,

aldehyde, acetic acid and acetic ether. It is neutralised with chalk and distilled. The product is repeatedly treated with chloride of calcium, until the latter is no longer moistened, and so rectified until its boiling point rises to 202° , when it is pure acetal. Its composition is as follows:—

Equiv.	By calculation.	By experiment.
8 C = 48	59.26	59.917 59.77 59.17
9 H = 9	11.11	11.222 11.58 11.29
3 O = 24	29.63	28.861 28.65 29.54
81	100.00	100.000 100.00 100.00

The formation of acetal depends on the oxidation of a portion of the hydrogen in alcohol, by the condensation of alcoholic vapor, and the air in the platinum-black. By removing 1 equivalent water and 2 of hydrogen from 2 equiv. of alcohol, acetal remains, thus:



It may be regarded as a compound of 1 eq. of acetic acid, and 3 eq. ether, $C_4H_3O_3 + C_{12}H_{15}O_3 = C_{16}H_{18}O_6$, or 2 eq. of acetal, but its probable rational formula deduced from its

behaviour to potassa, and sulphuric acid is C_4H_3O, HO, AeO which is a compound of aldehyde and ether. See **ACETIC ETHER**.

It is a colorless, mobile liquid, like ether, of a peculiar odor resembling Hungarian wines; boiling at 200° to 204° ; spec. grav. at 68° 0.823; soluble in 6 or 7 parts of water, and miscible in all proportions with alcohol and ether. By the gradual action of air and potassa it is converted into a brown substance, aldehyde-resin. Sulphuric acid renders it thick and brown. The farther action of platinum-black converts it into acetic acid and water. See *Aldehyde* under **ACETYLE**.

ACETATES. *Chem.* Compounds of acetic acid and metallic oxides, or organic bases. These salts are nearly all soluble in water, and easily crystallised; the acetates of molybdena and tungsten are insoluble, those of silver and suboxide of mercury are difficultly soluble. The oxygen in the acid is to that in the base as 3 to 1 in the neutral acetates. There exist also, with a few metals, basic salts, in which there is $1\frac{1}{2}$, 3, and 6 times as much base as in the neutral acetates. The neutral metallic acetates are formed both by direct union and by double decomposition, the basic by digesting the neutral with definite quantities of the base. The acetates of the fixed alkalies and alkaline earths subjected to distillation yield water and acetone (which see), while a carbonate of the base remains; the metallic salts yield a mixture of acetic acid and acetone, while the oxide and sometimes the reduced metal remains. The solutions of the alkaline acetates become mouldy by keeping, similarly to the acid.

The acid may be set free from its combinations by sulphuric acid, and is readily recognised by its characteristic odor, while its salts, in common with those of the organic acids, are blackened by heat.

The acetates are chiefly employed in dyeing and color-printing, of which they may almost be said to constitute the ground-work, the acetates of alumina, iron and lead being the most important.

The following table includes all the important acetates, those of the organic bases being introduced under the several bases. They may be written $MO + C_4H_3O_3$, or $MO + \bar{A}$ which is more easily read (the M standing for metal).

Acetate of	Formula	Equivalents.
1. Potassa	$KO + \bar{A} (C_4H_3O_3)$	98.26
2. Soda	$NaO + \bar{A} + 6 HO$	136.31
3. Ammonia	$NH_3 + HO + \bar{A}$	77.19
4. Baryta	$BaO + \bar{A} + 3 \text{ and } 1 HO$	154.67 and 136.67
5. Strontia	$SrO + \bar{A} + 4 \text{ and } \frac{1}{2} HO$	138.86 and 107.36
6. Lime	$CaO + \bar{A} + HO$	88.52
7. Magnesia	$MgO + \bar{A}$	71.69
8. Alumina	$Al_2O_3 + 3 \bar{A}$	204.00
9. Manganese	$MnO + \bar{A}$	86.72
10. Zinc	$ZnO + \bar{A} + 3 HO$	118.31
11. a. Protoxide of iron	$FeO + \bar{A}$	86.18
b. Sesqui or peroxide of iron ..	$Fe_2O_3 + 3 \bar{A}$	180.37

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Acetate of	Formula.	Equivalents.
12. Cobalt	$\text{CoO} + \bar{\text{A}}$	88.57
13. Nickel	$\text{NiO} + \bar{\text{A}}$	88.63
14. Lead, <i>a.</i> neutral.....	$\text{PbO} + \bar{\text{A}} + 3 \text{HO}$	189.73
<i>b.</i> sesquibasic	$3\text{PbO} + 2 \bar{\text{A}}$	437.19
<i>c.</i> tribasic	$3\text{PbO} + \bar{\text{A}}$	386.19
<i>d.</i> sexbasic	$6\text{PbO} + \bar{\text{A}}$	721.38
15. 1. Suboxide of copper	$\text{Cu}_2\text{O} + \bar{\text{A}}$	122.43
2. Oxide of copper, <i>a.</i> neutral ..	$\text{CuO} + \bar{\text{A}} + 5 \text{ and } 1 \text{HO}$	135.71 and 99.71
<i>b.</i> bibasic	$2\text{CuO} + \bar{\text{A}} + 6 \text{HO}$	184.42
<i>c.</i> sesquibasic	$3\text{CuO} + 2\bar{\text{A}} + 6 \text{HO}$	275.13
<i>d.</i> tribasic	$3\text{CuO} + \bar{\text{A}} + 3 \text{HO}$	197.13
<i>e.</i> hyperbasic	$48\text{CuO} + \bar{\text{A}} + 12 \text{HO}$	—
3. Acet. of copper and lime.....	$\text{CuO}, \bar{\text{A}} + \text{CaO}, \bar{\text{A}} + 8 \text{HO}$	242.23
16. Protoxide of tin	$\text{SnO} + \bar{\text{A}}$	117.93
17. <i>a.</i> Suboxide of mercury.....	$\text{Hg}_2\text{O} + \bar{\text{A}}$	261.86
<i>b.</i> Oxide of mercury.....	$\text{HgO} + \bar{\text{A}}$	160.43
18. Silver	$\text{AgO} + \bar{\text{A}}$	167.31

1. *Acetate of Potassa.* Chem. Phar. Syn. | *Lat.* *Acetas kalicus.* Formerly, *Terra foliata Ger. Essigsaures Kali.* *Fr.* *Acetate de potasse.* | *tartari, &c.*

Formula, $\text{KO}, \bar{\text{A}} (\text{C}_4\text{H}_3\text{O}_3)$

Composition in equivalents.	Form.	H = 1	O = 100	In 100 parts.
1 eq. acetic acid	$\text{C}_4\text{H}_3\text{O}_3 (\bar{\text{A}})$	51.00	637.98	52.16
1 " potassa	KO	47.27	589.92	47.84
1 " acetate of potassa	$\text{KO} + \bar{\text{A}}$	98.27	1227.90	100.00

It was first described by Raymond Lully, in the 13th century. It is found in some mineral waters.

Prep. Prepared by saturating acetic acid (vinegar) with carbonate of potassa, and evaporating to dryness, taking care always to have a slight excess of acid present, part of which it loses during evaporation, and without which the salt turns yellow or brown. The yellowish color may be removed by charcoal, particularly animal coal. Or precipitate acetate of lead by an excess of carbonate of potassa, filter, saturate free potassa with acetic acid, test for the presence of lead by sulphuretted hydrogen, and remove it by the same, and evaporate carefully to dryness. It crystallises with difficulty, when evaporated to a honey-consistence, in laminæ, but is generally obtained in a soft fibrous mass, which feels unctuous to the touch, and has a warm, pungent, sweetish and saline taste. It deliquesces in the atmosphere, and must be kept in closely stoppered bottles. It is soluble in alcohol, and the solution is decomposed by a current of carbonic acid gas; bicarbonate of potassa is deposited, and acetic ether is formed. At a boiling heat it dissolves

a considerable quantity of sulphate of lead, only part of which separates on cooling. The aqueous solution of acetate of potassa absorbs chlorine, and acquires powerful bleaching properties. The dry salt, distilled with arsenious acid, yields *alcarsine*. See *CACODULE*. Acetate of potassa exists in the juice of many plants, and when they are incinerated passes into carbonate of potassa.

Phar. Acetate of potassa is a powerful diuretic, and is frequently used in medicine. It should not be mingled with stronger mineral acids nor with the tartaric, nor with any salt having a stronger acid than acetic, and a feeble base than potassa.

According to Thomson a binacetate is formed by evaporating a solution of equivalents of acetate of potassa and acetic acid in vacuo over sulphuric acid. It crystallises in thin, broad transparent folia, and contains six eq. water. (*Liebig.*)

2. *Acetate of Soda.* Chem. Tech. Syn. *Lat.* *Acetas naticus.* *Ger.* *Essigsaures Natron.* *Fr.* *Acetate de soude.* Formerly, *Terra foliata tartari crystallisabilis.*

Formula, $\text{NaO} + \text{C}_4\text{H}_3\text{O}_3 + 6\text{HO}$ or $\text{NaO}, \bar{\text{A}}, 6 \text{aq.}$

Composition in equivalents.	Form.	H = 1	O = 100	In 100 parts.
1 eq. acetic acid.....	$\text{C}_4\text{H}_3\text{O}_3$	51.00	637.98	37.64
1 " soda.....	NaO	31.31	390.90	22.87
6 " water.....	6HO	54.00	675.00	39.49
1 " acetate of soda, cryst.....		136.31	1703.88	100.00

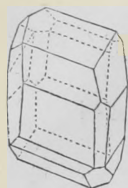
This salt was first prepared by Fr. Meyer, in 1767.

Prep. Prepared on the small scale as the preceding salt. Or by precipitating acetate of

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lead with an excess of carbonate of soda, neutralizing the filtered liquid with acetic acid, evaporating to the consistence of syrup, and allowing it to cool slowly.

Fig. 2.



Prop. Acetate of soda, by slow evaporation, crystallises in transparent, oblique, rhombic prisms (see Fig. 2), with its sharp lateral edges and corners replaced by planes, with 40·11 per ct. or 6 equiv. water. It has a pleasant, cooling, saline taste, is soluble in nearly 3 parts water at 60°, in its own weight of boiling water,

and in 5 parts alcohol; effloresces in a dry air; when heated, melts first in its water of crystallisation, with much frothing; in a higher temperature the dry salt again melts, and bears a low red heat without decomposition. The melted salt, on cooling, splits with a loud noise in all directions. If deliquescent, it is contaminated with acetate of potash. The details of its use by purifying pyroligneous acid, on a large scale, see under ACETIC ACID.

3. *Acetate and Binacetate of Ammonia.* *Chem. Phar.* Syn. Lat. *Acetas seu biacetas ammoniacus.* *Ger.* Essigsäures und saures essigsäures Ammoniak. *Fr.* Acet. et biacet. d'ammoniaque.

Formula of neutral salt, $\text{NH}_3 + \text{HO} + \text{C}_4\text{H}_3\text{O}_3$ or $\text{Am}, \text{aq.}$, or regarding ammonia as the oxide of ammonium. $(\text{NH}_4) \text{O} + \text{A}.$

Composition in equivalents (neutral salt).	H = 1	O = 100	In 100 parts.
1 eq. acetic acid..... $\text{C}_4\text{H}_3\text{O}_3$	51·00	637·98	66·30
1 " ammonia..... NH_3	17·19	214·47	33·70
1 " water..... HO	9·00	112·50	
1 " acetate of ammonia.....	77·19	964·95	100·00

Prep. and Prop. When equal weights of sal-ammoniac and acetate of potassa are distilled together at a very low temperature, ammonia is at first expelled, and binacetate of ammonia distils over as an oily liquid, which, on cooling, forms a radiated mass of transparent needles, deliquescent, and soluble in alcohol and water in every proportion. By passing dry ammonia into the melted binacetate, it becomes solid, and is converted into neutral acetate, which forms a white inodorous mass, very soluble in water and alcohol, with a feeble acid reaction, resolved by heat into ammonia and binacetate.

A diluted solution of this salt is much used as a diaphoretic in febrile diseases, under the name of *Liquor acetatis ammoniæ*, formerly *Spirit of Mindererus*, who introduced it as a remedy, particularly in Scotland. Boerhaave first described it in 1732. It is generally made by exactly neutralizing distilled vinegar with carbonate of ammonia. As distilled vinegar, however, varies much in strength, a better formula is to neutralize 6 parts of aqua ammoniæ, spec. grav. 0·96, with strong acetic acid, and to add as much water as makes up 24 parts. This solution is somewhat stronger than that of the British pharmacopœias; but it is uniform, and can easily be reduced.

The acetate is a clear liquid of a slightly pungent saline taste. It should react neither with red nor blue litmus-paper; concentrated sulphuric evolves acetic acid; lime or potassa evolves ammonia; sulphuretted hydrogen should produce no colour in it; acetates of silver or baryta should produce no precipitate; by heating it should entirely volatilize; the spec. grav. of the concentrated liquid is 1·04.

4. *Acetate of Baryta.* *Chem.* Syn. Lat. *Acetas baryticus.* *Ger.* Essigsäure Baryterde. *Fr.* Acetate de baryte.

Formula, $\text{BaO} + \text{C}_4\text{H}_3\text{O}_3 + \text{HO}$ (and, 3 HO), or $\text{BaO}, \text{A}, \text{aq.}$ (and 3 aq.)

Prepared by dissolving carbonate of baryta or sulphuret of barium in acetic acid, and evaporating the filtered liquid. It forms large, transparent, oblique, rhombic prisms (see Fig. 4), or irregular 8-sided prisms, when allowed to evaporate spontaneously. These crystals contain 17·5 per ct. or 3 eq. water, $\text{BaO}, \text{A}, + 3 \text{aq.}$ and are efflorescent in dry air, but retain their form. It is soluble in 1·75 parts cold and 1·03 pts. boiling water; 100 pts. of cold alcohol dissolve 1 pt., and 100 boiling take up 1½ parts of the salt. When evaporated at temperatures above 60°, or when effloresced, the crystals contain only 1 eq. water, 6·6 per ct. Formula, $\text{BaO}, \text{A} + \text{aq.}$ It is used in analysis to precipitate sulphuric acid, where it is desirable not to introduce nitric or muriatic acid. It is completely decomposed by heat into carbonate of baryta and acetone, thus $\text{BaO}, \text{C}_4\text{H}_3\text{O}_3 = \text{BaO} + \text{CO}_2$ and $\text{C}_3\text{H}_3\text{O}.$

5. *Acetate of Strontia.* *Chem.* Syn. Lat. *Acetas stronticus.* *Ger.* Essigsäure Strontianerde. *Fr.* Acetate de strontiane.

Formula, $\text{SrO} + \text{C}_4\text{H}_3\text{O}_3 + 4\text{HO}$ (and HO), or $\text{SrO}, \text{A}, 4 \text{aq.}$ (and aq.)

Obtained like the acetate of baryta. At temperatures below 60°, by spontan. evaporation it yields crystals (Fig. 4) containing 26 per ct. or 4 eq. water, which are efflorescent and soluble in 2½ parts water; by efflorescence or by crystallisation above 60° the crystals contain 4·23 per ct. water, or 2 eq. dry salt to 1 eq. water.

6. *Acetate of Lime.* *Tech. Chem.* Syn. Lat. *Acetas calcicus.* *Ger.* Essigsäure Kalkerde. *Fr.* Acetate de chaux.

Formula, $\text{CaO} + \text{C}_4\text{H}_3\text{O}_3 + \text{HO}$ or $\text{CaO}, \text{A}, \text{aq.}$

Composition in equivalents.	Form.	H = 1	O = 100	In 100 parts.
1 eq. acetic acid..... $\text{C}_4\text{H}_3\text{O}_3$		51·00	637·98	57·59
1 " lime..... CaO		28·52	356·02	32·22
1 " water... HO		9	112·50	10·19
1 " acetate of lime, cryst.....		88·52	1106·50	100·00

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Prepared like the preceding by dissolving carbonate of lime in acetic acid. The simple hydrated acid does not attack carbonate of lime. (*Pelouze*.)

The salt is obtained in large quantity in the preparation of pyroligneous acid for the manufacture of white lead, sugar of lead, &c., but this acid being nearly replaced by vinegar from the oxidation of alcohol, at least in this country, the manufacture of the acetates of soda and lime is at present limited. They are both, however, employed in dyeing operations.

Tech. The commercial salt usually contains an excess of lime. 1000 lb. wood-vinegar, 127½ lbs. chalk, and 24 lbs. caustic lime, give about 198 lbs. of (pyrolignite) acetate of lime. To make a common acetate of alumina, dissolve 100 lbs. alum in 50 galls. water, and

then add a solution of 150 lbs. acetate of lime of strength 12° B.

It crystallises in silky needles, of an astringent, bitter, and saline taste; effloresces at 212° becoming an anhydrous powder; heated to 226° and triturated in the dark, it phosphoresces strongly, and at a higher heat decomposes like the acetate of baryta; readily soluble in water, with more difficulty in alcohol. See farther under *Acetic Acid*.

7. *Acetate of Magnesia.* *Chem.* Prepared from carbonate of magnesia like the preceding, is a deliquescent gummy mass, when concentrated, crystallising with difficulty, insoluble in alcohol. Formula $MgO + \bar{A}$.

8. *Acetate of Alumina.* *Tech. Chem. Syn. Lat.* *Acetas aluminicus.* *Ger.* Essigsäure Thonerde. *Fr.* Acetate d'alumine ou d'argile.

Formula, $Al_2O_3 + 3C_4H_5O_3$, or $Al_2O_3, 3\bar{A}$.

Composition in equivalents.	Form.	H = 1	O = 100	In 100 parts.
3 eq. acetic acid.....	3 ($C_4H_5O_3$)	153.00	1913.94	75.03
1 " alumina.....	Al_2O_3	51.43	642.33	24.97
		204.43	2556.27	100.00

Best prepared by precipitating sulphate of alumina by acetate of baryta. Uncrystallisable, drying into a gummy mass, very soluble in water and of a very astringent taste; decomposed by slight heat into acetic acid and a subacetate of alumina. Gay-Lussac found that the solution may be boiled without decomposition, but that when impure, from the presence of a neutral alkaline salt, the solution becomes turbid from the deposition of an insoluble salt which redissolves on cooling.

Tech. *Syn.* Red liquor, Acetic alum-base, *Ger.* Essigsäure Thonbeitz, *Roth- und Gelbbeitze.* *Fr.* Mordant rouge. It is the last-named property which gives it a high value in the various operations of the dyer and color-printer, and the solution of the salt has generally received the name of *Red liquor*, from the practice of sightening it, or rendering it visible with a little red color, such as a decoction of peach wood, Brazil-wood, &c. It is not simply acetate of alumina, but a mixture of acetate or binacetate and sulphate or subsulphate of alumina with sulphate of potassa, as will be evident from its preparation. If we had neutral sulphate of alumina, we might then simply add an equivalent of it to an equivalent of acetate of lead, in order to procure a solution of neutral acetate of alumina; but the commercial aluminous salt being a double salt, or a sulphate of alumina and sulphate of potassa, (formula, $KO, SO_3 + Al_2O_3, 3SO_3 + 24aq.$), we should add an equiv. of acetate of lead for each of the three equiv. of sulphuric acid combined with the alumina, or by weight 570 pts. (= 3 eq.) acet. lead, to 475 (or 1 equiv.) of alum. It is found in practice, however, to be most advisable to employ equal parts of alum and sugar of lead or rather less of the latter, the former dissolved in boiling water and the latter subsequently added in powder. It is usual to add a $\frac{1}{10}$ or less of soda crystals (carbonate of soda) to the alum, or a little whiting (carbonate of lime), to neutralize a portion of the sulphuric acid. The three following recipes may serve to illustrate this:

No. 1. In 50 galls. boiling water dissolve 100 lb. alum, and when dissolved, add 100 lb. acet. lead in fine powder, stirring the mixture well at first and several times during cooling, and when clear, the supernatant liquid is acid acetate of alumina and sulphate of potassa, with a little subsulphate of alumina.

No. 2. In 50 galls. boiling water dissolve 100 lbs. alum, and to the solution add slowly 10 lbs. 6 " crystallised soda, and then stir in 100 lbs. 50 " acetate of lead in fine powder, as before.

Both Nos. 2 and 3 contain acid acetate of alumina, basic sulphate of alumina dissolved in acetic acid, and sulphates of potassa and soda. No. 2 becomes cloudy at 154° F., and gelatinizes at 165°. No. 3 clouds at 176°, and gelatinizes at 192°. No. 2 stands at 14° Beaumé. No. 3 at 10°. A mordant of 4 pts. water, 3 pts. alum and 3 pts. acetate of lead shows 14° B. and does not cloud in boiling.

An inferior aluminous mordant is made by adding acetate of lime (pyrolignite of lime) to alum, but the former being generally used in solution, the number of gallons of the former

are given to lbs. of the latter. The decomposition is similar to that above, where acetate of lead is employed, excepting that the decomposition is not as complete, and a portion of sulphate of lime remains in solution to the detriment of bright colors. See also *Acetate of Lime*.

According to the experiments of Köchlin-Schouch, it appears that acetate of alumina is not the only active agent in red liquor, but that a part of the alum is wholly converted in a basic sulphate, which combines with acetate of alumina, and that this double salt is dis

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solved in an acid acetate of alumina. While the based goods are drying, a portion of acetic acid volatilizes, a part of the basic acetate combines with the basic alum, and by passing through the dung-bath, another portion of acetic acid is removed, which completes the combination of the basic aluminous salts with the goods. It is hence unnecessary to decompose all the alum by acetate of lead, since the remaining salt acts as a base as well as pure acetate of alumina, when the due proportions are attended to, such as

16 pts. water by weight or 32 gallons.	
4 " alum.....	64 lbs.
$\frac{1}{18}$ " soda.....	1 "
$\frac{3}{8}$ " acetate of lead..	4 "

Köchlin-Schouch asserts from his experiments that it is less economical, and that it is immaterial for depth and tone of color to employ 100 alum to 125 or 75 acetate of lead, but Runge has shown that it is not immaterial, but more advantageous to take 100 alum to 120 acetate of lead (or in equiv. 474 to 570, see above), but that the quantity of water in either case is important and should not be the same as was employed by K.-S. Thus cotton dipped in the 2 color bases (mordants)

No. 1. 100.....	No. 2. 100 alum.
75.....	120 acetate of lead.
280.....	448 water,

and dyed in the same madder-bath, give the same shade and tone of color; but the cotton fibre cannot completely decompose the former, as shown by two experiments. Two equal weights of cotton based, one in No. 1, the other in No. 2, hung up in the same place, left for the same time, and then washed in equal volumes of hot water, much alum was obtained from the wash-water of No. 1 and scarcely a trace

Formula, $\text{MnO} + \text{C}_4\text{H}_3\text{O}_3$, or $\text{MnO}, \bar{\text{A}}$.

Composition in equivalents.	Form.	H = 1	O = 100	In 100 parts.
1 eq. acetic acid	$\text{C}_4\text{H}_3\text{O}_3$	51.00	637.98	59.06
1 " protoxide of manganese ..	MnO	35.72	445.89	40.94
1 " protacetate of manganese		86.72	1083.87	100.00

Prep. by dissolving carbonate of manganese in acetic acid, or on a large scale by adding neutral sulphate of manganese to acetate of baryta, lime or lead, filtering and evaporating in part. It crystallises in plates or rhombic prisms of an amethyst color, unchangeable in the air, dissolves in $3\frac{1}{2}$ cold water, soluble in alcohol. The concentrated solution is employed like the sulphate of the same metal in dyeing, chiefly in calico-printing, being thickened and printed on the cloth, and passed through a bath of chloride of lime, when the protoxide is converted into hydrated oxide of a rich and very permanent brown color. It may also be passed through a bath of caustic alkali, potassa, or lime, when the precipitate on the cloth, at first nearly white, passes into a brown hydrate by oxidation. (See **DYEING** and **CALICO-PRINTING**.) The cheapest method of preparing this salt pure, consists in precipitating the sulphate of manganese in a great measure by acetate of lime, and the balance by acetate of

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from No. 2, so that much alum is actually lost by the use of No. 1. Runge has however not taken into view the neutralization of a portion of the sulphuric acid by carbonate of soda, which, by bringing basic salts into action, materially changes the subsequent operations of drying, and undoubtedly fastens a larger amount of alumina on the piece than without its use; and although in this case a portion of alum may be washed out after drying, yet it may be doubted whether the advantage of using so large a proportion of acetate of lead is not counterbalanced by its great expense.

Acetic alum-bases, or mordants which deposit basic sulphate of alumina by heat, become clear again on cooling, but a deposit made after the lapse of time remains undissolved even by an excess of acetic acid.

Acetate of alumina, obtained from the decomposition of 100 parts sulphate of alumina by 115 acetate of lead, contains no undecomposable sulphate of alumina and no sulphate of potassa; the single colored grounds produced by this color-base are livelier, more even, and fuller than those from the ordinary mixed acetate, or red liquor. See **ALUMINA**, *Sulphate of*. (*Runge & Vitalis*.)

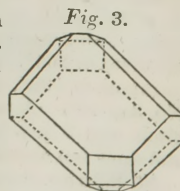
The acetic alum base is largely employed in calico-printing, organic fibre decomposing it more readily than the sulphate of alumina in alum, and hence attaching to itself more alumina with which the richest hues are produced. It is chiefly employed with madder for reds; with quercitron, French berries, fustic, &c., for yellows, the various tints depending in part on the strength of the solution. Details of its use will be given in the articles **DYEING** and **CALICO-PRINTING**.

9. *Acetate of Manganese. Chem. Tech. Syn. Lat. Acetas manganosus. Ger. Essigsäures Manganoxydul. Fr. Acétate de manganèse.*

lead. To make the best acetate, to 4 parts of sulphate of manganese add 7 parts of crystallised acetate of lead, each dissolved in 3 parts of water, stir well, let it settle and draw or filter off the clear liquor.

10. *Acetate of Zinc. Chem. Phar. Form. $\text{ZnO} + \bar{\text{A}} + 3\text{H}_2\text{O}$.* Prepared by dissolving zinc or oxide of zinc in acetic acid, or by double decomposition from the sulphate of zinc like the preceding salt. It crystallises in flexible, brilliant, 6-sided tables (*Fig. 3*), of a pearly talc-like lustre, which effloresce slightly in dry air. By spontaneous evaporation it forms a beautiful dendritic efflorescence. According to Schindler it contains 22.5 per ct. or 3 eq., when prepared by heat only one eq. water.

It is, unlike the other salts of zinc, completely precipitated by sulphuretted hydrogen, if neutral. It is used in medicine for the same pur-



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poses as the sulphate, and in pharmacy for preparing cyanide of zinc.

Tech. The best method of preparing it for the dyer is to dissolve 4 pts. sulphate of zinc and $7\frac{1}{2}$ pts. acetate of lead each in 3 pts. water, to mix them well together, filter, and let it crystallise.

11. *Acetates of Iron.* Of these we have two, one of the proto- and the other of the peroxide.

a. *Acetate of Protoxide of Iron.* *Chem. Syn.* *Lat.* *Acetas ferrosus.* *Ger.* *Essigsäures Eisenoxydul.* *Fr.* *Proto-acetate de fer.* Prepared by dissolving sulphuret of iron, or iron in acetic acid, or less perfectly by mingling copperas with acetate of lead. Should peroxide be present it may be reduced to protoxide by sulphuretted hydrogen, a little free acid having been previously added. It crystallises in small green prismatic crystals, very soluble in water,

Formula, $\text{Fe}_2\text{O}_3 + 3 (\text{C}_4\text{H}_3\text{O}_3)$ or $\text{Fe}_2\text{O}_3, 3\bar{\text{A}}$

Composition in equivalents.	Form.	H = 1	O = 100	In 100 parts.
3 eq. acetic acid	3 $(\text{C}_4\text{H}_3\text{O}_3)$	153.00	1913.94	66.35
1 " peroxide of iron.....	$\bar{\text{Fe}}_2\text{O}_3$	78.37	978.41	33.65
1 " acetate of peroxide of iron.....		231.37	2892.35	100.00

Tech. The dyer employs nominally both acetates, but from the rapid oxidation of the former he employs a mixture of the two, or still better the peracetate; the calico printer, on the other hand, frequently prefers the salt as nearly a protacetate as possible.

a. *The Protacetate of Iron or Iron Liquor.* *Syn.* *Pyrolignite of iron.* *Ger.* *Holzsaures Eisenoxydul, Eisenbeizte, Eisenbrühe, Schwartzbeizte, Schwartztonne.* *Fr.* *Tonne au noir, Bouillon noir.* This important mordant may be prepared either by the direct union of its component parts, or by double decomposition. 1. The first method is now generally practised, and consists in digesting pyroligneous acid, of a specific gravity of 7°T. ($5\frac{1}{4}^\circ \text{B.}$) upon an excess of clean malleable iron, in a state of minute division, till the liquor has acquired a specific gravity of 18°T. (12°B.) at the temperature of 60°F. , ascertained by cooling a small quantity dipped from the boiler from time to time, and testing it by the hydrometer. A large cast iron boiler should be employed, and the liquor kept at a temperature not to exceed at any time 150°F. If clean wrought iron turnings be used, and in considerable excess, the process may be completed in from 5 to 7 days. Considerable tar rises during the solution, which should be skimmed off: a still heavier scum will continue to rise after the liquor is cold, and, indeed, for days and months afterwards, a part of which it is better to allow to remain undisturbed, till the liquor is wanted for use, and more particularly if it is exposed to the action of the air in an open cistern. The water is decomposed in this operation, its hydrogen passing off in the gaseous state, and its oxygen uniting with the iron forming the protoxide with which the acid unites.

Some printers prepare this liquor without heat; but the process described is preferable; when the solution is effected without heat, the tar attaches to the surface of the iron, impedes the action of the acid, and renders the process

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and rapidly oxidizing in the air. Its alcoholic solution, known as *tinctura acetatis ferri*, is not much used at present.

b. *Acetate of Sesquioxide of Iron.* *Chem. Tech.* *Syn. Lat.* *Acetas ferricus.* *Ger.* *Essigsäures Eisenoxyd.* *Fr.* *Peracetate de fer.* Made by dissolving pure hydrated peroxide of iron in acetic acid, or by mingling acetate of baryta and persulphate of iron. It is an uncrystallisable, dark brownish red solution, which by evaporation forms a deliquescent gelatinous paste. Like the acetate of alumina, it deposits an insoluble, basic peracetate when heated, and hence its utility in dyeing operations. *Basic acetate of peroxide* is an insoluble yellow powder, precipitating out of the protacetate which has oxidized in the air, and even out of the neutral peracetate when kept for some time, if an alkaline salt be present.

extremely tedious; there is also in the latter case more risk of peroxidizing the iron, particularly if the liquor be much exposed to the air by pumping, or pouring it backwards and forwards from one vessel to another, as erroneously recommended by most writers on this subject, and still practised by many calico printers.

From 100 gallons of pyroligneous acid, with the requisite quantity of iron, from 60 to 70 gallons of iron liquor at 18°T. (12°B.) may be obtained. This solution, reduced to 12°T. ($8\frac{1}{2}^\circ \text{B.}$) is sufficiently strong to produce a deep black with madder.

2. This mordant may also be obtained by the double decomposition of the acetate of lead, or lime, and the protosulphate of iron; for this purpose,

Take 1 gallon of water,
4 lbs. of protosulphate of iron, &c.,
2 lbs. of acetate of lead.

Dissolve the sulphate of iron in the water, and then add the sugar of lead; stir the mixture till the decomposition is complete, which is almost instantaneous, if the solution of copperas be hot when the lead is added: when the sulphate of lead has subsided, decant the clear liquor. There remains a considerable excess of undecomposed copperas in this solution.

The acetate of lead is, however, never used for this mordant, unless as an extemporaneous preparation, when the acetate of lime is not at hand. To prepare the iron mordant from the latter,

Take 75 gallons solution of pyrolignite of lime at 16°T. ($11^\circ \text{B.};$)
400 lbs. of protosulphate of iron (green copperas;)
100 gallons of water.

Dissolve the copperas in the water by heat, then add the pyrolignite of lime, and stir well together; when the precipitate has subsided,

decant the clear liquor. This liquor at 60° Fah. will have a specific gravity of 22 T. (15° B.) and reduced to 12° T. (8½ B.) by the addition of water, is supposed to have about the same strength as that prepared by the direct solution of iron in the pyroligneous acid of the same hydrometrical strength.

To prevent peroxidation where this mordant is kept on hand for a considerable length of time, as it must often be, we may add small quantities of clean iron turnings, which will detach and combine with the oxygen of the peracetate, restoring it again to the protacetate, and unite with and neutralize the free acid. To prevent too great an accumulation of sediment in the casks or cistern, by these additions of iron, the turnings may be suspended in the liquor by a coarse netting. (Porter.)

Another method of making protacetate of iron, practised in Europe to a limited extent, is to add to a solution of pure acetate of lead, protocarbonate of iron as long as a precipitate of carbonate of lead takes place. The clear liquor then decanted from the white lead may be heated with clean iron turnings to charge it fully with neutral acetate of iron. This acetate is said to be superior, and the white lead pays the cost of manufacture.

In the manufacture of protacetate, pyroligneous acid is preferable to common vinegar, as the empyreumatic matter it contains prevents more or less the higher oxidation of the iron, and its dark color is of no perceptible influence, since iron liquor is only employed for darker colors.

b. Peracetate of Iron. Syn. The same as for the Iron Liquor, except *Ger.* Holzsaures Eisenoxyd. Where the dyer requires uniform grounds, he cannot as well employ the proto-salts of iron, for when cotton is impregnated with such a solution as coppers or the preceding salt, while drying it attracts oxygen from the air, and the peroxide of iron or a basic persalt collects more in those parts not yet dry, and will of course produce darker spots in the dye-bath. It is, therefore, better to prepare an acetate of the peroxide at once, either by pouring acetic acid repeatedly over iron turnings for several weeks, in vessels exposed freely to the air, or still better by double decomposition with sugar of lead or acetate of lime. For this purpose dissolve 1 lb. iron-alum (see IRON-ALUM), in 4 lbs. (½ gall.) water, add 1 lb. acetate of lead, stir the liquor well, let it settle, and decant or filter. The solution made from iron-alum will not keep long, as it gradually deposits an insoluble basic salt from the presence of sulphate of potassa (see the first part of this article on *Acetate of Sesquioxide of Iron*), while those made from persulphate of iron will retain their properties for a great length of time, but, on the other hand, iron-alum is more convenient in use, from its containing known quantities of peroxide of iron, and the difficulty may be obviated by preparing only the quantity required for immediate use.

The peracetate of iron may also be made from persulphate of iron and acetate of lead. See IRON, persulphate of. As the persulphate of iron is not so uniform a composition as the

iron-alum, it may be well to ascertain how much oxide of iron and sulphuric acid it contains, in order to know what quantity of acetate of lead to employ in its decomposition. For this purpose weigh out 100 grains, which is about ½ an equiv. of dry and pure persulphate, dissolve in water, and filter; add 285 grs. cryst. acetate of lead (½ of 3 eq.) dissolved in water filter and weigh the precipitate, which is sulphate of lead; every 76 grs. of this sulphate of lead require 95 or more, safely 90, grs. of acetate of lead to insure sufficient decomposition. Calling grains pounds, the operation may then be conducted on a large scale. The excess of acetate of lead in the acetic iron mordant may be ascertained by diluting a little of the clear liquor with water, and adding a few drops of sulphuric acid; if it becomes cloudy, there is an excess of acetate of lead, which may prove injurious to colors; but it is easily obviated by adding a little more persulphate of iron, until the clear liquor is no longer clouded by sulphuric acid. For the ordinary operations of the dyer, it may not be necessary to decompose all of the persulphate of iron, but for printing, and particularly for full russets, the whole salt should be peracetate of iron, since otherwise some of the sulphate would disappear in washing the goods, while they may be fully charged with basic acetate of iron which cannot be removed by water.

Conclusion. Much space has been devoted to the acetates of iron and alumina, from their great importance in the arts of dyeing and color-printing, and it is to be regretted that those engaged in these beautiful and useful arts, which require an intimate knowledge of chemical science as well as practice, are generally so deficient in the former.

The acetates of iron are employed in woollen-dyeing, to produce blue with prussiate of potassa, in cotton-dyeing and printing, and in silk-dyeing, for blacks, russets, &c.; the protacetate with madder for violet; the same, together with acetic alum base, for brown; in dyeing hats and furs black, for blackening leather, wood, &c. Some prefer the protacetate, because by the oxidation of the iron subsequent to dyeing, the colors are more permanent; but the use of peracetate insures greater uniformity of the ground.

The peracetate of iron containing protacetate, may also be conveniently made by pouring pyroligneous acid on iron turnings in a series of vessels placed obliquely one above the other, as will be more particularly described under *Acetate of Lead*, suffering the acid to remain the same length of time in contact with the metal, and repeating the operation twice, or until the acid is saturated.

12. *Acetate of Cobalt.* Chem. Form. $\text{CoO} + \overline{\text{A}}$. Prepared by dissolving oxide or carbonate of cobalt in acetic acid. It is red in solution, blue when dry. 1 pt. oxide dissolved in acetic acid, and mingled with ¼ pt. common salt forms a good sympathetic ink, the writing being scarcely visible when cold, and bluish green when heated.

13. *Acetate of Nickel.* Chem. Form. $\text{NiO} + \overline{\text{A}}$. Prepared from nickel oxide or its carbonate,

as the preceding. Green crystals, of sweetish taste, soluble in 6 pts. water, not in alcohol, effloresces slightly in the air.

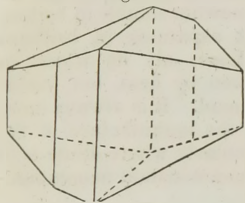
Both the acetates of nickel and cobalt, when perfectly neutral, are entirely thrown down by sulphuretted hydrogen, as sulphurets of the metals.

14. *Acetates of Lead.* There are four com-

Formula, $\text{PbO} + \text{C}_4\text{H}_3\text{O}_3 + 3\text{HO}$ or $\text{PbO}, \bar{\text{A}}, 3 \text{ aq.}$				
Composition in equivalents	Form.	H = 1	O = 100	In 100 pts.
1 eq. acetic acid.....	$\text{C}_4\text{H}_3\text{O}_3$	51.00	637.98	27.08
1 " oxide of lead.....	PbO	111.73	1394.50	58.71
3 " water.....	3HO	27.00	337.50	14.21
1 " acetate of lead, cryst.....		189.73	2369.98	100.00

Prep. By dissolving litharge or white lead in acetic acid, or by the action of acetic acid and air on metallic lead, and evaporating the solution with an excess of acetic acid to prevent the formation of basic salts. Rapidly cooled, it crystallises in needles; slowly, it forms transparent, white, right-rhombic prisms, with dihedral summits, (Fig. 4). It has a disagreeably sweetish taste (hence its former improper name), metallic, astringent; soluble at common temperatures in $1\frac{1}{2}$ pts. water and 8 pts. alcohol; when perfectly fresh, and from a neutral solution, it has a neutral

Fig. 4.



reaction; but the carbonic acid of the air slightly decomposes it, and acetic acid being set free, it gives an acid reaction. Ammonia does not precipitate the aqueous solution, but changes it into a tribasic salt; heated with an excess of ammonia, it throws down crystalline oxide of lead; heated gently, loses crystalline water, and becomes anhydrous; and it may be heated to 161° with the loss of scarcely any acid, but fusion rather hinders the escape of the water; at a higher heat the dry salt fuses, and forms the sesquibasic acetate (see the next salt), while carbonic acid and acetone escape.

Phar. Latterly much employed in medicine. Given internally as pills, or in solution, in diarrhœa, dysentery, pulmonary catarrh, and hæmorrhages. Free acetic acid should be given at the same time, to prevent the formation of carbonate, which is really the poisonous compound. (Turner.)

Tech. This salt, so important in the arts of coloring, is made upon the principles stated above. 1. By dissolving oxide of lead (litharge, massicot) in good acetic acid, not in pyroligneous, unless pure, for its empyreumatic matter may affect the light colors by mordants made from it. It may be done in vessels of lead, or even in copper, provided the latter have pieces of lead soldered in its interior, which by its electric action renders the copper more electro-negative, and prevents its being dissolved. 13 pts. finely ground and sifted oxide of lead is gradually added to 23 pts. strong vinegar of 7° B. moderately heated and stirred, to prevent adhering to the bottom. When solution is effected, dilute with washings of previous pro-

pounds of acetic acid and the protoxide of lead, containing different proportions of acid and oxide.

a. Neutral Acetate of Lead. *Chem. Syn.* Sugar of Lead, Salt of Saturn. *Lat.* *Acetas plumbicus*, *Saccharum Saturni*. *Ger.* *Essigsauers Bleioxyd*, *Bleizucker*. *Fr.* *Acetate de plombe*, *Sucre de Saturne*, *Sel de Saturne*.

cesses, heat to boiling, cool slowly, to let it settle, draw off clear liquor, and test its alkalinity by litmus-paper. If it have an alkaline reaction, add vinegar, until there is a decided acid reaction, when it may be evaporated to the density of 32° B. and run into the crystallisers, always taking care that the solution have an acid reaction. By the above process we should obtain something less than 22 pts. crystallised acetate of lead.

The crystallisers may be of stone-ware, or wood, their edges being greased to prevent the travelling vegetation of the salt; they may swing on an axle, so that after crystallisation they may be inclined and the liquor gently run off without disturbing the crystals during drainage, and strips of wood may be laid across to prevent the crystals forming in the liquid from accumulating on the bottom and crushing the lower stratum to powder. After drainage, they are dried in a stove-room at $80-85^\circ$ on linen or paper, but it should be noted that paper, wood, linen, &c., imbued with acetate of lead and well dried, will, when fired, burn like tinder.

The mother liquor, containing neutral and basic acetates of lead and other metallic salts, may either be treated with vinegar, evaporated, re-crystallised, and the residue employed as washings, in subsequent operations, or it may be decomposed by carbonate of soda or lime and used as carbonate of lead, or dissolved in acetic acid, and the supernatant acetate of soda or lime employed for acetic acid or in dyeing.

2. The following process with metallic lead, recommended first by Berard, is easily executed, and yields a good product with great economy. Granulated lead, the tailings in the white-lead manufacture, &c., are put in several vessels (say 8), one above the other, on steps, so that the liquid may be run from one to the other. The upper one is filled with acetic acid, and after $\frac{1}{2}$ hour let off into the 2d, after another $\frac{1}{2}$ hour into the 3d, &c., and so on to the last or 8th vessel. The acid causes the lead to absorb oxygen rapidly from the air, evolving heat, so that when the acid run off from the lowest is thrown on the upper vessel for the second time, it forms a certain quantity of acetate of lead in solution, and after passing through the whole series is so strong that it may be evaporated at once to crystallise. (Runge.)

There are two points of importance in this manufacture, whatever method may be pur

sued, to employ a strong acid that less time and acid may be lost in concentrating the liquid—and, in addition, to keep the liquid always acid to prevent the formation of a basic salt.

Copper may be detected in acetate of lead, by its bluish color, by ammonia in excess, which gives a blue solution, or by prussiate of potassa. Its bluish color is often hidden, by packing it in blue paper. It is sometimes adulterated by acetate of lime, which, according to Buchner, is best detected by dissolving in water containing a few drops of nitric acid, and adding a solution of tartaric acid as long as a precipitate occurs. It is then filtered, and after standing 24 hours deposits crystals of tartrate of lime, if lime be present. It may also be detected in a short time by dissolving as before, adding pure hydrosulphuret of ammonia as long as it precipitates, filtering and adding oxalate of ammonia. White oxalate of lime precipitates.

Acetate of lead is chiefly employed in dyeing and color-printing, sometimes alone, as a mordant for chrome-yellow and orange, and a mixed green, generally to prepare acetates of alumina, iron and tin; to manufacture the pigments chrome-yellow and orange; in chemistry to make strong acetic acid, acetic ether, acetone, basic acetate of lead, varnish, &c.

b. Sesquibasic Acetate of Lead. Chem. Form. $3\text{PbO} + 2\text{A}$. Made by gently heating (530° Mitscherlich) neutral dry acetate of lead (see *a*) in a porcelain capsule or retort, until the fluid mass congeals to a porous white mass, dissolving in water, evaporating to a syrupy consistence and set aside, when it crystallises in pearly, 6-sided scales in concentric groups, unchangeable in air and in vacuo; very soluble in water and alcohol, shows alkaline reaction; carbonic acid precipitates white lead, rendering the salt neutral; by digestion with litharge yields tri- and sexbasic acetate. Formation, 3 equiv. neutral acetate lose one of dry acid, which passes off as acetone and carbonic acid. See ACETONE. (*Liebig*.)

c. Tribasic Acetate of Lead. Chem. Phar. Form. $3\text{PbO} + \text{A}$. Syn. Subacetate of lead. Trisacetate of lead. *Lat.* Acetas tri-plumbicus. *Ger.* Dritt essigsures Bleioxyd, Bleiessig (when in solution). *Fr.* Vinaigre de plomb. A cold saturated solution of neutral acetate is mixed with one-fifth of its volume of aqua ammoniæ and set aside, when the trisacetate is deposited in long silky needles, which are anhydrous and very soluble in water. Or, to obtain it in solution, 7 parts of litharge are digested, with frequent agitation, with a solution of 6 parts of sugar of lead in 30 of water, in a close vessel, till the oxide which remains undissolved has become quite white. If it contain copper, it is precipitated by putting in pieces of metallic lead, or according to Jeiseler, better by previously freeing the litharge of copper by carbonate of ammonia.

The solution, evaporated in a retort, to exclude carbonic acid, which it rapidly absorbs, forms a white opaque mass, consisting of minute needles, very soluble in water, insoluble in alcohol. The liquor plumbi subacetatis

of the pharmacopœias is a solution of this salt, always containing some neutral and sesquibasic acetate, unless a large excess of litharge be employed. It is much used as a lotion, and has long been known as Goulard's extract, or Goulard's water. It is a clear and somewhat thick liquid, of a sweetish taste, has a strong alkaline reaction, and absorbs carbonic acid from the atmosphere, becoming turbid from the deposition of carbonate, slowly deposits the sexbasic acetate. For this reason it is far more poisonous than the sugar of lead, as it has a much greater tendency to form the very poisonous carbonate. Antidotes are the alkaline sulphates. It precipitates solution of gum, and is used as a test for that substance. It yields precipitates with almost all organic acids, even those which are not precipitated by the neutral acetate. It further precipitates albumen, caseous matter, and extractive matter, and is much employed to remove such substances from organic mixtures. (*Lieb. and Greg.*)

d. Sexbasic Acetate of Lead. Chem. Form. $6\text{PbO} + \text{A}$.—Prepared by adding any other acetate of lead in solution to an excess of ammonia. A white crystalline (under the microscope) precipitate, somewhat soluble in boiling water, from which it separates in brilliant feathery crystals. Loses all its water in vacuo, does not blacken by heat, but yields acetone and carbonic acid. It is always more or less produced in the manufacture of the acetates of lead, particularly where dilute acid is employed; it is also a constant accompaniment of white lead.

Tech. The above basic acetates are all found in the arts, the last named being generally an unintentional product. There is a subacetate prepared by digesting 1 eq. acetate of lead (=190 pts.) with one eq. litharge (112 pts.), or better 9 lbs. crystallised acetate and 6 lbs. litharge (allowing for some impurities in the latter). The acetate is dissolved in water (tinned vessels may be used) and while steam is run through, the litharge is gradually added, or it must be stirred to prevent the adhering of the sexbasic salt to the bottom if heated over a fire in copper vessels. Strips of lead should be laid or soldered in the vessels to prevent the solution of copper and to remove what copper may exist in the materials. This solution, which is chiefly the tribasic acetate, but contains also neutral and sesquibasic acetate, is an important salt in the arts of coloring, since by mingling with an equivalent of it an equiv. of bichromate of potassa, we get chrome-yellow directly, or an equiv. of yellow chromate of potassa we obtain chrome-orange. Besides this point of economy, the subacetate has also a stronger attraction for cotton-fibre, and hence less is lost in cleansing printed goods where it is employed. See DYEING, *Chrome-colors*.

The basic acetate is also employed in making white lead by precipitation with carbonic acid. See WHITE LEAD.

15. *Acetates of Copper.* There is one acetate of the suboxide of copper, and several acetates of the oxide, one of which is neutral, and the others basic.

1. *Acetate of Suboxide. Chem. Form.* $\text{Cu}_2\text{O} + \text{A}$

Syn. Acetate of protoxide of copper. Obtained by decomposition of neutral acetate of copper by dry distillation, depositing itself in the upper part of the retort as colorless, pearly scales, or as a voluminous, snowy vegetation. Rapidly decomposes in air (*Berzelius*), unchanged in moist air (*Liebig*), with water decomposes into hydrated suboxide of copper, and by presence of air into acetate of oxide of copper, occurs in verdigris, and is the cause of the red residue (suboxide of copper), when

this substance is dissolved in distilled vinegar, slightly soluble in spirits of wine.

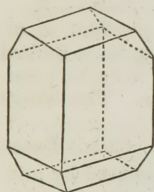
2 a. Neutral Acetate of Copper. Chem. Tech. *Syn.* Distilled or crystallized verdigris. *Lat.* *Acetas cupricus cum aqua. Ger.* Neutrales essigsaures Kupferoxyd, Destillirter Grünspan. *Fr.* Acetate de cuivre, Deuto-acetate d. c., Verdet cristallisé, Vert en grappes, Cristaux de Venus. Formerly used for preparing glacial acetic acid by dry distillation, and hence the name distilled verdigris.

Formula, $\text{CuO} + \text{C}_4\text{H}_3\text{O}_3 + \text{HO}$, or CuO , A aq.

Composition in equivalents.	Form.	H = 1	O = 100	In 100 pts.
1 eq. acetic acid.....	$\text{C}_4\text{H}_3\text{O}_3$	51.00	637.98	51.40
1 " oxide of copper.....	CuO	39.71	495.70	39.61
1 " water.....	HO	9.00	112.50	8.99
1 " acetate of copper, cryst.		99.71	1246.18	100.00

Prepared by dissolving verdigris in acetic acid, or precipitating an equivalent sulphate of copper (see this) by an equiv. acetate of lead and crystallising the filtered liquid. It forms dark-green, oblique, rhombic prisms, with oblique terminating planes (*Fig. 5*); taste disagreeable, metallic; soluble in 13.4 cold and 5 pts. boiling water, and slightly soluble in alcohol. Heated in the air it burns with a lively green flame; subjected to dry distillation; it yields first water, then acetone, acetic acid and gaseous matter, leaving finely divided metallic copper, which is easily inflammable; the yield is 48—49 pr. ct. of acetic acid containing acetone. A solution of it mingled and heated with honey, sugar, &c., is decomposed, depositing minute red octahedral crystals of suboxide of copper, while the liquor contains also formic acid.

Fig. 5.



Heated in the air it burns with a lively green flame; subjected to dry distillation; it yields first water, then acetone, acetic acid and gaseous matter, leaving finely divided metallic copper, which is easily inflammable; the yield is 48—49 pr. ct. of acetic acid containing acetone. A solution of it mingled and heated with honey, sugar, &c., is decomposed, depositing minute red octahedral crystals of suboxide of copper, while the liquor contains also formic acid.

By dissolving verdigris in water acidulated with acetic acid and crystallising below 46° , it forms oblique 4-sided prisms of the color of blue-vitriol, the formula of which is $\text{CuO} + \text{A} + 5 \text{ aq.}$; when heated to 86° , they suddenly become opaque and green, and consist of fine crystals of the common neutral acetate, with one eq. of water, losing 4 eq. which are retained by the salt like a sponge. (*Wöhler*.)

Tech. Rarely employed in pharmacy; generally used as a green pigment (sap-color); formerly for obtaining concentrated acetic acid; also employed in dyeing, and calico-printing as resist-paste in the blue vat dyes, &c.; its use in the latter case depending on the reduction of the oxide of copper to the suboxide while the indigo is thus oxidized previous to its contact with the cloth, with which it cannot then combine.

b. Bibasic Acetate of Copper. Chem. Tech. Syn. Subacetate of copper, Verdigris. *Lat.* *Acetas bi-cupricus, aerugo. Ger.* Grünspan, Zweifach basisches essigsaures Kupferoxyd. *Fr.* Bisous-acetate de cuivre, Vert-de-gris, Verdet.

Formula $2 \text{ CuO} + \text{C}_4\text{H}_3\text{O}_3 + 6 \text{ HO}$, or 2 CuO , A, 6 aq. which may be read CuO , A, 5

aq. + CuO , aq. which regards it as the blue neutral acetate combined with the hydrated oxide of copper.

The following analyses compared with the theoretic composition shows in a measure its liability to variation.

	<i>French V.</i>	<i>English V.</i>	<i>Theory.</i>
Acetic acid	29.3	29.62	27.85
Oxide of copper	43.5	44.25	42.93
Water	25.2	25.51	29.22
Impurities	2.0	0.62	
	100.0	100.00	100.00

Prepared by exposing plates of copper to the fermenting marc of the grape, or wrapping them in cloths dipped in acetic acid; the former product is blue, the latter, green. The acid here evidently induces the more rapid oxidation of the copper with which it then unites, similar to the process described for forming acetate of lead (see above). It forms a hard and tough mass, of a blue, bluish-green, or green-color, difficult to pulverize; with a metallic coppery taste; separated by cold water into the two following basic salts; heated to 140° it loses water and leaves 76.5 pr. ct. of a green mass, consisting of neutral and tribasic acetate, both with water of crystallisation. (*Berz.*)

Tests of Verdigris.—It should be dry, have a fine, full, bluish-green color, be almost wholly soluble in dilute acetic and sulphuric acids and in ammonia, and by ignition in close vessels leave a residue of copper mixed with carbon.

Phar. The acetates of copper are now rarely employed internally, and in but few external applications; in the latter case as an ointment. Prepared by washing over the powdered verdigris, and collecting the fine powder which settles.

c. Sesquibasic Acetate of Copper. Chem. Form. 3 CuO , 2 A , 6 aq. Verdigris is treated with warm water, and the solution suffered to evaporate spontaneously or mixed with alcohol. It is a blue amorphous mass, or in crystalline scales from the alcoholic treatment, readily soluble in hot, difficultly in cold water, insoluble

ble in alcohol. Heated to 212° loses 10 pr. ct. $\equiv 3$ eq. water. A saturated solution heated to boiling deposits a brownish powder, and becomes neutral. (See below.) Constitutes the principal part of the greener kinds of verdigris (*Berz.*); according to Liebig they contain on an average 46—50 pr. ct. oxide of copper; the blue varieties 43—44 pr. ct.; and the tribasic is the chief ingredient of the green varieties.

d. Tribasic Acetate of Copper. Chem. Form.

$3 \text{ CuO}, \bar{A}, 3 \text{ aq.}$ Remains when verdigris is exhausted of the soluble salts by water, or by digesting a solution of neutral acetate with hydrated oxide of copper. It is a light green powder, losing no water at 212° , tasteless; burning when heated with a little deflagration; not decomposed by carbonic acid; by boiling water becomes brown, while the neutral salt is dissolved. (*Liebig.*) The most permanent acetate of copper. (*Berz.*)

e. Hyperbasic Acetate of Copper. Is formed when any of the basic acetates of copper are boiled for some time with water; the more dilute the less heat is required, so that even a very dilute solution of the neutral salt deposits it. In the liquid it is of a liver-brown color; when dry, black, slightly soluble in water, deflagrates slightly, when heated. Composed of 92.3 oxide of copper, 2.45 acetic acid, and 5.25 water, the formula for which would be $48 \text{ CuO}, \bar{A}, 12 \text{ aq.}$

Tech. The manufacture of verdigris is generally conducted in a simple manner, and undoubtedly might be improved. The process employed at Montpellier and Grenoble in France is still the same, being chiefly conducted by the females in farm-houses.

The husks of the grape, not entirely pressed out, are stamped in casks and kept in a cool place for subsequent use. When wanted, they are filled loosely in several casks or earthen pots, covered with straw mats to produce acetous fermentation. The proper degree of fermentation is ascertained by putting in a test sheet of copper for 24 hours, which should come out covered uniformly with a green coating; if not, it is suffered to remain another day or until the proper fermentation takes place. The copper sheets are prepared by hammering out thick sheet copper till about the $\frac{1}{2}$ inch ($\frac{1}{2}$ line) thick, to consolidate the metal; the harder, the better; it is cut into sheets 5—6 inches long by 3 broad, which weigh about 4 ounces each. When first used, they are previously rubbed with a solution of verdigris and dried, as without this they would become black instead of green. They are next heated over a charcoal fire so hot that they must be held by a cloth, and alternately layered with the fermenting husks in the casks, having a layer of the latter at top and bottom, and covered with straw mats. The casks contain some 30—40 lbs. They are opened after 12—20 days, and when the process is complete, the uppermost layer of husks is whitish, and the plates covered with silky crystals. The plates are removed, and dried for 2 or 3 days by setting them upright against each other; then moistened by dipping them in water and again

placed to dry as before. This operation of moistening and drying is repeated some 6—8 times at regular weekly intervals. The plates swell uniformly, becoming covered with an increasing coat of verdigris, which is scraped off with a copper knife, each vessel of 40 lbs. yielding 5—6 lbs. in the fresh state (*vert de gris, frais, humide*). This is kneaded into a paste with water, stuffed in leathern bags and dried in the sun, losing 40—50 pr. ct. in weight, until they become hard and tough like the commercial article. The scraped plates are again employed until entirely converted into verdigris (*Chaptal.*)

At Grenoble (France) they moisten the plates with vinegar, and in England, Germany, Sweden, &c. they make alternate layers of the plates and cloths dipped in acetic acid (pyroligneous in Engl.) in wooden boxes. The cloths are moistened with the acid every three days, and after 12 days small crystals appear, when they are moistened with water once per week, the cloths are omitted and a small space between the plates left for the circulation of air. The operation is complete in 5 to 6 weeks. Verdigris is also made by rolling sheet copper and putting it in pots containing vinegar, as in the manufacture of white lead. (*Schubarth.*)

Verdigris is employed as a pigment in oil painting, in lacquering, bronzing, to a limited extent in dyeing, as resist-paste in calico printing, in the hat manufacture, &c. The bluish green is regarded as the best.

3. Acetate of Copper and Lime. Chem. Form.

$\text{CuO}, \bar{A} + \text{CaO}, \bar{A} + 8 \text{ aq.}$ Prepared by mingling together solutions of acetate of copper and acetate of lime, and evaporating to crystallise. Large, fine, dark-blue crystals, soluble in water, from which the white acetate of lime effloresces after some time. Formerly used in color printing, but is inferior to the acetates of copper alone.

16. Acetate of Protoxide of Tin. Chem. Tech.

Form. $\text{SnO}, \bar{A}$. *Syn.* Protacetate of tin. *Ger.* Essigsäures Zinnoxidul. *Fr.* Proto-acétate d'étain. Prepared by precipitating 103 pts. crystallised protochloride of tin by 136 cryst. acetate of soda, or 190 cryst. acetate of lead, or by dissolving protoxide of tin, or metallic tin in acetic acid, the last is inconvenient, the 2d yields it pure, the 1st is the technical operation. Evaporated to a syrupy consistence and alcohol poured into it, crystallises in colorless transparent needles, with a nauseous, styptic taste, oxidizing readily in the air, and cannot then be crystallised, being acetate of peroxide. Employed in calico-printing for light spirit colors, the best proportions being 30 lbs. acetate of lead dissolved in 40 lbs. boiling water, to which add $18\frac{1}{2}$ lbs. cryst. tin salt, stir well, let it settle for 3 to 4 days, and keep it as much as possible from the air in close vessels. It is so likely to oxidize that it should be made only immediately before using.

17. a. Acetate of (black) Suboxide of Mercury. Chem. Phar. Syn. Protacetate of mercury. *Ger.* Essigsäures Quecksilberoxydul. *Fr.* Proto-acetate de mercure. *Form.* $\text{Hg}_2\text{O} + \text{C}_4\text{H}_3\text{O}_3$, or $\text{Hg}_2\text{O}, \bar{A}$.

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Composition by equivalents.	Form.	H = 1	O = 100	In 100 parts.
1 eq. acetic acid	$C_4H_3O_3$	51·	637·98	19·64
1 " suboxide of mercury	Hg_2O	210·87	2631·65	80·36
1 " acetate of suboxide of mercury		261·87	3269·63	100·00

The combination of mercury and acetic acid was known to Le Febur in the 17th century; Stahl and Marggraff extended our knowledge of it; Stromeyer, in 1809, distinguished between the acetates of the oxide and suboxide, or the red and black oxide.

Prep. Obtained by dissolving pure suboxide or its carbonate in acetic acid, or by mingling hot solutions of subnitrate of mercury and acetate of soda or potassa. Pure subcarbonate, obtained by decomposing subnitrate by neutral carbonate of potassa and washing the precipitate, is heated to boiling with 8 pts. water, and concentrated acetic acid added until all is dissolved; the hot filtered liquid free from oxide is suffered to cool; or acidulated subnitrate of mercury is diluted with 6—8 pts. water, heated, and mingled with an equivalent of acetate of soda or potassa, dissolved in 8 pts. hot water, containing a little free acid, and suffered to cool. (4 pts. dissolved mercury require 1 pt. acetate of potassa, or rather a little more of the latter, and less than 1 of acetate of soda.) The

salt, when separated, is washed with a little cold water, dried in the dark at a gentle heat, and kept from the light in covered bottles.

Prop. It crystallises in fine, white, silvery scales, flexible and unctuous to the touch; with a nauseous, metallic taste; easily decomposed by light; decomposed and wholly volatilized by heat, difficultly soluble in cold water, requiring 33 pts. at common temperatures, much more so in hot. Partially decomposed by boiling water into acid and basic salts of both oxides and metallic mercury; in cold alcohol insoluble, in hot decomposed by the separation of suboxide.

Phar. Formerly given internally in powder or pills, and supposed not to produce salivation; this is, however, not true, and it is now little used. Very easily decomposed by acids, alkalies, and many salts. (*Liebig.*)

b. Acetate of Oxide (red) of Mercury. Chem. Syn. Peracetate of mercury. *Lat.* Acetas hydrargyricus. *Ger.* Essigsäures Quecksilberoxyd. *Fr.* Peracetate de mercure.

Formula, $HgO + C_4H_3O_3$, or $HgO, \bar{A}$.

Compositions by equivalents.	Form.	H = 1	O = 100	In 100 parts.
1 eq. acetic acid	$C_4H_3O_3 (\bar{A})$	51·	637·98	32·02
1 " oxide of mercury	HgO	109·44	1365·82	67·98
1 " acetate of mercury	$HgO, \bar{A}$	160·44	2003·80	100·00

Prepared by digesting red oxide of mercury in concentrated acetic acid, with gentle heat, and evaporating to dryness, or partially to crystallise and suffering it to evaporate spontaneously. By the first it is a white saline mass, by the 2d, crystalline scales; by the 3d, 4-sided plates, partly transparent, partly pearly and translucent; anhydrous, of a nauseous, metallic taste; fusible without decomposition, solidifying to a granular mass, but its point of decomposition is near that of fusion. Dissolves in 4 pts. of water at 50° in 2·75 at 66·2° and in 1 at 212°, but by boiling it is partially decomposed, with the separation of the red

oxide; even in the air its solution suffers the latter change, and becomes a basic salt; with free acetic acid it is not decomposed. 100 pts. alcohol dissolve 5½, and this is similarly affected with its aqueous solution. It generally contains, except when carefully crystallised, some suboxide.

Phar. Now rarely employed, but the two acetates entered into the composition of Keyser's pills.

18. *Acetate of Oxide of Silver. Chem. Syn.* Acetate of silver, Acetas argenticus. *Ger.* Essigsäures Silberoxyd. *Fr.* Acetate d'argent.

Formula, $AgO, \bar{A}$.

Composition by equivalents.	Form.	H = 1	O = 100	In 100 parts.
1 eq. acetic acid	$C_4H_3O_3 (\bar{A})$	51·00	637·98	30·70
1 " oxide of silver	AgO	116·31	1451·61	69·30
1 " acetate of silver	$AgO, \bar{A}$	167·31	2089·59	100·00

Prep. and Prop. By dissolving the oxide or its carbonate in acetic acid, or by mixing hot concentrated solutions of acetate of soda or potassa, and nitrate of silver, in nearly equivalent quantities, the former rather predominating. Separates in pearly, flexible, needle-shaped crystals, which are light and voluminous; taste strongly metallic; anhydrous; requires 100 pts. cold water for solution. Easily decomposed by heat, pure acetic acid passing

off and metallic silver remaining, which retains the form of the crystals.

From the slight solubility of the acetate of silver, the nitrate of that metal is a convenient reagent to determine approximately the quantity of acetic acid in analysis; salts of molybdena and tungsten are better. It is also a useful reagent for chlorohydric acid, particularly with the acetates.

The remaining salts of acetic acid, which

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have been more or less examined, are of little | their composition and characteristic proper-
utility, and are given in a tabular form with | ties.

Table of less important Acetates.

Name.	Formula.	Properties.
Acetate of Lithia.....	$\text{LO} + \bar{\text{A}} \dots\dots$	Deliquescent, gummy mass.
“ Glucina.....	$\text{G}_2\text{O}_3 + 3 \bar{\text{A}} \dots\dots$	Very soluble gummy mass.
“ Yttria	$\text{YO} + \bar{\text{A}} \dots\dots$	Rosy crystals, permanent.
“ Zirconia	$\text{Zr}_2\text{O}_3 + 3 \bar{\text{A}} \dots\dots$	White powder, deliques., solub. in water and alcohol.
“ Thorina	$\text{ThO} + \bar{\text{A}} \dots\dots$	White, amorphous, forms double salts.
“(Proto) Cerium....	$\text{CeO} + \bar{\text{A}} \dots\dots$	Fine needles, permanent, very sol. in alcohol.
“ Cadmium.....	$\text{CdO} + \bar{\text{A}} \dots\dots$	Fine needles, perman., very sol. in water.
“ Bismuth	$\text{BiO} + \bar{\text{A}} \dots\dots$	White scales, similar to boracic acid.
“ Uranium.....	$\text{U}_2\text{O}_3 + 3 \bar{\text{A}} \dots\dots$	Topaz-yellow, right square prisms.
“ Rhodium.....		Red solution.
“ “ and soda		Red salt, sol. in water, insol. in alcohol.
“(Proto) Platinum..	$\text{PtO} + \bar{\text{A}} \dots\dots$	Greenish solution, dark brownish-green when dry.
“ Antimony	$\text{Sb}_2\text{O}_3 + 3 \bar{\text{A}} \dots\dots$	Small white crystals, very soluble.
“(Proto) Molybdena..	$\text{MoO} + \bar{\text{A}} \dots\dots$	Dark gray powder, black when dry, insoluble.
“ Molybdena....	$\text{MoO}_2 + 2 \bar{\text{A}} (?)$	Yellow solut., gelatiniz. on cooling.
“ Molybdic acid	$\text{MoO}_3 + 3 \bar{\text{A}} (?)$	Yellow powder, slightly soluble in water.
“ Vanadium ...	$\text{VO}_2 + 2 \bar{\text{A}} (?)$	Blue solut., dark green cryst. soluble in water, with green color.
“ Chrome.....	$\text{Cr}_2\text{O}_3 + 3 \bar{\text{A}} \dots\dots$	Green, imperfectly crystalline, soluble.

ACETIC ACID. Syn. Aceticum acid, Vinegar. *Lat.* Acidum aceticum. *Ger.* Essigsäure, Essig. *Fr.* Acide acétique, Vinaigre.

It has been known from ancient times that the expressed juice of fruits, after becoming vinous by a species of fermentation, was subject to another change under certain circumstances, by which it became sour to the taste, which conversion we call the acetous fermentation, and the acid is termed vinegar or acetic acid. It was evidently impossible prior to the rise of chemical science, and even for some time subsequent to it, to investigate the theory of these changes, in consequence of the variety of ingredients contained in the liquids, and the apparent variety of circumstances producing the change. Although there are many points which remain to be cleared up in some of the practical details of the acetous fermentation, yet we are enabled to lay down one principle as its cause in nearly all the processes of making vinegar, excepting one, the rationale of which remains for future investigation, viz. its formation by the distillation of wood. In the formation of acetic acid from alcoholic liquids, it depends upon oxidation by the atmosphere, but in the case of substances which are capable of undergoing the alcoholic fermentation, the transition to the acetous is often so rapid that the intermediate saccharine and

alcoholic changes are imperceptible. (See under ACETOUS FERMENTATION.) We shall first show theoretically the change of pure alcohol into acetic acid, and then describe, 2, the practical operation founded on it; 3, the making of vinegar from fruits and grain; and 4, the manufacture of pyroligenous acid or wood vinegar by the destructive distillation of wood; and lastly describe the properties and uses of acetic acid.

1. *Theoretic View.* Dr. J. Davy discovered that alcohol in contact with platinum-black (see this) rendered it incandescent and produced acetic acid. Döbereiner showed that alcohol by the absorption of oxygen is converted into acetic acid and water, without the evolution of carbonic acid gas, and that one equiv. alcohol requires 4 eq. oxygen to produce the change. Oxidizing substances, such as binoxide of manganese or bichromate of potassa, with dilute sulphuric acid also convert alcohol into acetic acid. The change is not, however, instantaneous, but consists of two consecutive stages, the 1st being the absorption of 2 eq. oxygen, which, combining with 2 eq. hydrogen remove them as water, forming *aldehyde* (which see) and 2d, the further absorption of 2 eq. oxygen, which unite with the elements of aldehyde and produce acetic acid.

Thus to..... $\text{C}_4\text{H}_5\text{O} + \text{aq.} = \text{alcohol}$, add O_2 , which
remove..... $-\text{H}_2 + \text{O}_2 = 2 \text{HO} = 2 \text{ water}$,
leaving..... $\text{C}_4\text{H}_3\text{O} + \text{aq.} = \text{aldehyde} \& 2\text{HO}$,
add O_2 O_2 and there is formed

$\text{C}_4\text{H}_3\text{O}_3 + \text{aq.} \& 2 \text{HO} = \text{hydrated acetic acid (or } \text{C}_4\text{H}_3\text{O}_3 + 3 \text{HO, which is a terhydrate of acetic acid.)}$

Now aldehyde is a very volatile liquid, | be likely to form when there is a deficiency of
which, according to the above formula, would | oxygen, and indeed it is always produced in the

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manufacture of acetic acid by the oxidation process, and in larger quantity when the access of air is too limited.

The apparatus described under *Acetal*, Fig. 1, may be employed to show the oxidation of alcohol; and it was there stated that acetal, aldehyde, and acetic acid were produced, and by the continued action of the *black*, the whole would be converted into acetic acid and water.

The same change takes place in alcoholic liquids, which contain certain organic substances, such as yeast, malt, wine, honey, vinegar, &c., which are themselves subject to oxidation in the air, the change first taking place on a nitrogenous substance or substances included in them; pure alcohol in any state of dilution is not oxidized by the air alone. In the use of platinum-black we ascribe acetification to the condensation of alcohol and the oxygen of the air in the porous mass (see *Absorption*), while the black is unaltered by the operation. Now De Saussure has shown that nearly all organic substances condense a mixture of oxygen and hydrogen, bringing them in such close contact that they combine and form water, and hence we may infer that a mixture of alcohol and oxygen might be converted by them into acetic acid and water. The nature of the altering substances will be more minutely discussed under *Ferment*. The changes produced by the conversion of alcohol into acetic acid have been referred by Berzelius and others to the operation of a new force called Catalysis, in which it is supposed that the presence or contact of certain bodies produces decompositions and new combinations; but, without resorting to such an unknown or but imperfectly known power, we may explain it on the principle above laid down, that of the absorption and condensation of air (oxygen). The difference between the two cases above noticed are, that the platinum-black is not altered when it produces acetification, but the ferments are themselves decomposed while inducing fermentation. It is not improbable that the ferment absorbs oxygen and resolves itself into a highly oxidized body, which, by giving up a portion of oxygen to the alcohol, evolves carbonic acid and water. Where the ferment has been decomposed and precipitated as insoluble matter, after a long-continued vinous fermentation, as is the case with some wines, and in the low fermentation of Bavarian beer, these liquids lose the tendency to acetification.

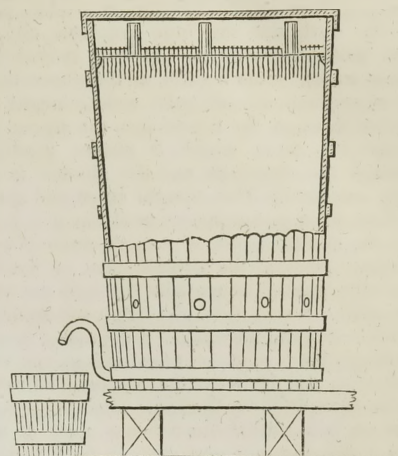
2. *a. Quick Vinegar Process.* Ger. Schnellesigbereitung. The manufacture of acetic acid by direct oxidation is now conducted on a large scale in Europe and the United States by following out the principles above given, and affords an interesting example of the application of the modern discoveries in organic chemistry to the useful arts. In 1823, Schützenbach, Wagenmann and Kastner (it is difficult to say who first proposed it) made important improvements in Boerhaave's old process for the acetification of distilled liquors, by paying due regard to an increased temperature, admitting the air more freely, and exposing a very extended surface to its action. Alcohol is thus completely acidified in 24 to 48 hours.

The oaken vats or vessels in which the

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oxidation takes place are termed graduators, graduating vessels, in German, Essigbilder or vinegar-generators. Fig. 6. They are 5—7 ft.

Fig. 6.



high, $3\frac{1}{2}$ ft. diameter below, 3 ft. wide above, placed $1\frac{1}{2}$ ft. above the ground, and provided with a wooden cover, fitting rather closely, and having a funnel inserted in its centre, through which the alcoholic liquid is to be poured. A broad wooden hoop is fastened closely around the inside about 6 inches from the top, on which rests the false top, leaving a small space between it and the sides, to be stopped tightly with tow. This is perforated with some 200—300 small holes, of 2 lines ($\frac{1}{8}$ inch) diameter and about $2\frac{1}{2}$ inches apart, through each of which pass strips of cotton or linen wick, with knots on the upper end to prevent their passing through; 4 larger holes $1\frac{1}{2}$ inches diam. and $1\frac{1}{2}$ ft. apart, are each fitted air-tight, with a glass tube, 4 to 5 inches long, which, opening a little below and several inches above the false top, allows the air of the interior to pass out slowly. About 1 ft. to 15 inches from the bottom, 8 holes are bored, sloping downwards, at equal distances, in a circle around the vat, through which the air enters, without suffering the liquid to flow out. The whole vat is then filled with beech-wood shavings to within an inch of the false top; they should be previously scalded with water and soaked in heated vinegar.

The liquid is poured into the vat through the funnel, and trickles dropwise through the cotton wick; to prevent it running too fast, the wicks should fill the holes, and the false top fit closely to the sides; spreading among the shavings it offers a very extended surface to the action of the air entering through the 8 holes, and is more or less oxidized. The air having performed its part, passes out through the 4 glass tubes, and finally through the funnel in the cover. To prevent the liquid from collecting in too great quantity at the bottom, a glass syphon is introduced an inch or two from the bottom, so that its upper bend is an inch at least below the 8 holes, and runs off the liquid into the receiving vessel or bucket. A thermometer is sometimes introduced a little below the false top, to observe the temperature of the oxidating compartment of the vat.

To charge the vats, a standard liquid is employed, consisting of 50 galls. brandy, whisky, &c., of 60 per cent. measured, and 37 gallons clear beer or malt wine. When the vats are first put in operation, acetification takes place slowly, until the shavings are well charged with mother of vinegar (acetous ferment), to attain which some 5 galls. of the above liquor are mixed with 40—50 galls. weak vinegar, and poured through the funnel into the upper part of the vat, from which it passes gradually through the shavings, and the alcohol is partially oxidized. The vinegar employed should be free from pyroligneous acid, for it is found that the essential oils, or a mere trace of wood vinegar, prevent the acetification of alcohol. It is then poured repeatedly through the same vat, until it comes through completely acidified, which requires many days. A deposit of mother gradually takes place on the shavings and sides of the vat; and the larger the amount of it formed, the more rapid the oxidation, so that the process goes on better after some weeks, than at first. The vats being thus prepared, 15 to 18 galls. of the standard liquor is diluted with some 60 galls. soft water, and poured into the 1st vat, then into the 2d; every hour $2\frac{1}{2}$ galls. are drawn off from the 2d, the product of 1 hour being kept as vinegar, that of the next hour being thrown back on the 1st vat. Thus, in 24 hours, 30 galls. are ready for sale. With 10 vats, which one hand can superintend, 150 galls. acetic acid may be made daily in 17 working hours. This acetic acid is as clear as water, and may be compared to distilled vinegar in appearance and purity; but to make it more saleable, and like wine vinegar, we may add to every 50 galls. about 1 lb. cream of tartar, 2 lbs. sugar or molasses, sufficient to give a good color. By using honey or molasses in the spirits, we can at once obtain it of a good color from the vats, some indeed add it on the score of economy.

It is important that the temperature be somewhat elevated. When the operation is commenced, the room should have a temperature of about 100° , and the preparatory mixture be heated to 120 — 130° when poured through. When the vats are in full operation, the vinegar room should be maintained at 68 — 73° , and the liquid be heated to 75 — 83° ; but the rapid oxidation then develops so much heat that the thermometer in the oxidating compartment indicates 100 — 104° , which it maintains as long as the operation goes on favorably.

Where a stronger vinegar is required, the product of the 2d vat is mixed with a stronger alcoholic liquid, and passed through a 3d vat; and for a still stronger, a 4th vat is employed, with the addition of proof spirit to the product of the 3d; but it should be noted that the weaker spirituous liquors are more easily and rapidly acetified than the stronger, and that the latter are more subject to waste. The vinegar obtained by the above proportions is of such a strength that an ounce will neutralize 30—36 grs. carbonate of potassa; by a 3d vat, with 25 instead of 16—18 galls. of the standard liquor, an ounce neutralizes 45 grs.; with a 4th, it has been made to neutralize 50—60 grs. carbonate of potassa.

The malt wine alluded to, is made by infusing 80 lbs. pale barley-malt and 40 lbs. pale wheat malt, ground and extracted, with $37\frac{1}{2}$ galls. water at 120° F., then with 75 galls., and well mashed. After several hours' rest, draw off the wort from the settlings, and when cooled to about 72° stir in 15 lbs. yeast, and set it to ferment 2 or 3 days in a loosely-covered tun. When the vinous fermentation is complete, the clear liquor is drawn off by an opening a little above the sediment, so that the latter and the scum remain. In the employment of other materials than distilled spirits in making vinegar by the direct oxidation process, the lees, dregs, and solid matters floating about in the liquids, as in the above and other beers, or such insoluble matters as are formed in them during acetification, are apt to collect among the shavings, and clog the free passage of air and liquid. Hence, clear liquors should always be employed, and then the vats may be used for a considerable time.

It is found that, according to the theory above given (1), $C_4H_6O_2$, absolute alcohol = 46 (lbs.) should yield 51 (lbs.) dry acetic acid, which would neutralize 69 (lbs.) dry carbonate of potassa; so that 200 galls. spirits of 50 per ct. (measured), containing 792 lbs. absolute alcohol, yield, when diluted, 1900 galls. acetic acid, every ounce of which neutralizes 30 grs. carbonate of potassa, and in general every per cent. of alcohol in the liquors yields as much acetic acid as will neutralize 5 grains.

It is found, in good practice, that the above quantity actually yields 1667 galls. of 32 grs. neutralizing power, which is equal to 1775 galls. at 30 grs. Hence, the loss, which is about $6\frac{1}{2}$ per ct., shows the perfection of the process. Attempts have been made to obviate this slight loss, by conducting the air escaping through the funnel over cold water, but the small amount of evaporated fluid thus restored does not repay the trouble of saving it. Another more important source of loss from imperfect oxidation will now be pointed out.

Under 1, it was shown that there is a lower oxide than acetic acid, which is more liable to form when there is an insufficient supply of oxygen; this is aldehyde, a colorless volatile liquid, characterized by its forming a brown insoluble compound with potassa. Now, if we close some of the 8 openings in the vats, diminishing thereby the supply of oxygen (in the air), and test the liquid which passes through by a solution of caustic potassa, we shall invariably obtain a brown solution or precipitation of aldehyde-resin. With the dimensions of the holes above given, where all are open, little or no brown substance can be obtained by potassa; with larger openings, none can be found. The formation and great volatility of aldehyde is the chief cause of loss in this process, and to obviate it we must offer a sufficient supply of oxygen. But, on the other hand, if we increase the openings, and allow a too strong current of air to pass through the vats, a considerable portion of alcohol is carried off at the same time; so that a proper medium, neither too great nor too small a quantity of air must be admitted, in

order to conduct the process with the greatest success.

Not only does the general process of acetification of alcohol by this method offer a clear proof of the value of theoretic knowledge, when properly applied, but even in its details shows how the apparently useless discoveries of the theoretic chemist may be made available to the perfection of the arts. Thus it was often a subject of wonder how some vinegar establishments, apparently conducted in a proper manner, could never obtain the requisite quantity of acetic acid. Liebig discovered aldehyde—referred it to a low oxidation of alcohol, which, by a larger supply of the same, would become acetic acid: with his characteristic quickness he applied it to this manufacture, showing that the losses observed were due to the formation of aldehyde, from an insufficient supply of air, and that by increasing the openings, to admit more air, it would be completely obviated.

b. Wine Vinegar. *Ger.* Weinessig. *Fr.* Vinaigre. Acetic acid is conveniently made from wines in wine-growing countries; but even in many of them the quick vinegar process seems destined to expel the slow acetous fermentation as a manufacture. The latter is, however, still conducted in many places, particularly in France, in the northern part of which, Orleans wine-vinegar has been celebrated. In the Orleans vinegar establishments (*vinaigreries*), they usually employ 3 or 4 rows of vats or casks, of some 45 galls. content each, lying horizontally, with two holes adjoining in the upper part of the front end; one of which, 2 inches diameter, is for charging the cask with wine, and removing the finished vinegar; the other, which is much smaller, is designed for the influx and efflux of air. When the casks (*Fr.* *Mères de vinaigre*—mothers of vinegar) are first employed, they are filled $\frac{1}{2}$ with the best wine-vinegar, boiling, adding $2\frac{1}{2}$ galls. wine. In 8 days a second charge of $2\frac{1}{2}$ galls. is introduced; and thus a 3d, 4th, &c., after intervals of 8 days each, until the proper quantity has been added, or when the casks are $\frac{3}{4}$ full: 8 days after the last charge, about 9 galls. vinegar are drawn off, provided the fermentation has been successful, and wine added in the same quantities and times as before. One of these mothers (casks) will make twice its content of vinegar annually (less than 100 galls.)

To ascertain whether the vinegar is in a good state of fermentation (*travail*) after the last charge, a white rod, bent at one end, is thrust into the cask, and drawn out horizontally; if it be covered with a thick, white froth (*fleur de vinaigre*), the fermentation is complete, otherwise it is gray or reddish. In the latter case the heat of the apartment is increased, to hasten its completion. Summer temperature is generally sufficient of itself, but in winter the vinegar-house is warmed to 75—85°.

Tartar, lees, mother, &c. gradually collect and form sediment on the bottom of the casks, impeding the fermentation, and rendering the vinegar liable to become turbid. In the latter case, the turbid acid is thrown into a vessel

containing beech shavings, and in a short time drawn off clear. Turbid wines are cleared in a similar manner. When the deposit has increased too much, the contents of the cask are cleared out. Under favorable circumstances a cask will last 20 years.

c. Boerhaave's old process for making acetic acid from wines and brandies is still followed in France, on the Rhine, in Holland, &c. The fermentation takes place in two large wooden vats or hogsheads, in each of which is placed a wooden grate or hurdle, at the distance of a foot from the bottom. The vessel is set upright, and in the grate a moderately close layer of green twigs or fresh cuttings of the vine is placed. The vessel is then filled up with the foot-stalks of grapes, commonly called the rape, twigs of willow, &c., to the top of the vessel, which is left quite open.

The two vessels being thus prepared, the wine or diluted spirits is poured in; one is filled quite up, the other but half-full. They are left thus for twenty-four hours, and then the half-filled vessel is made quite full from the liquor of that which was before entirely so; this, in its turn, will be only half-full.

Four-and-twenty hours afterwards the same operation is repeated and proceeded in, the vessels being alternately kept full and half-full during the twenty-four hours, till the vinegar is made.

On the second and third day, there will arise in the half-filled vessel, a fermentative motion, accompanied with a sensible heat, which will gradually increase from day to day. On the contrary, the fermenting motion is almost imperceptible in the full vessel; and as the two vessels are alternately full and half-full, the fermentation is, by this means, in some measure interrupted, and is only renewed every other day in each vessel.

When this motion appears to have entirely ceased, even in the half-filled vessel, it is a sign that the fermentation is finished; and, therefore, the vinegar is then put into casks, closely stopped, and kept in a cool place.

A greater or less degree of warmth accelerates or checks this, as well as the spirituous fermentation. In France, it is finished in about fifteen days, during the summer; but if the heat of the air be very great, and exceed 25° Reaum. or 88° Fahr. the half-filled vessel must be filled up every twelve hours; because, if the fermentation be not so checked in that time, it will become violent, and the liquor will be so heated, that many of the spirituous parts on which the strength of the vinegar depends, will be dissipated, so that nothing will remain after the fermentation but a rapid liquor, sour indeed, but effete.

The better to prevent the dissipation of the spirituous parts, it is a proper and usual precaution to close the mouth of the half-filled vessel, in which the liquor ferments, with a cover made of oak wood. As to the full vessel, it is always left open, that the air may act freely on the liquor it contains; for it is not liable to the same inconveniences, because it ferments very slowly. (*Gray.*)

By changing every 12 hours and keeping the temp. of the apartment at 83°, by which the

fermentation was completed in 6—8 days, an approximation was made to the quick vinegar process, by rapid oxidation.

3. *Acetic acid from fruits, grain, and sugar.*

a. *Fruits.* The juice of grapes, apples, and other saccharine fruits is expressed, subjected to the vinous fermentation in casks at a temp. of 77—82°. If muddy, they should be filtered through beech wood shavings, &c., to clarify, and then suffered to acetify in vinegar casks, adding a little vinegar to commence and hasten the operation. (Compare the process for wine vinegar, 2. b.)

b. *Sugar.* Brown or white sugar, syrup, honey, molasses, &c., may be made to undergo the acetous fermentation by first subjecting them to the vinous by means of yeast. The two following processes given in *Ure's Dict. Arts*, under *acetic acid* may be advantageously followed.

"In 158 quarts of boiling water dissolve 10 pounds of sugar, and 6 pounds of wine-stone; put the solution into a fermenting cask, and when it is cooled to the temperature of from 75° to 80°, add 4 quarts of beer-yeast to it. Stir the mixture well, then cover the vessel loosely, and expose it for 6 or 8 days to the vinous fermentation, at a temperature of from 70° to 75° Fahr. When it has become clear, draw off the vinous liquor, and either acetify it in the graduation tub above described, or by the common vinegar process. Before it is finished, we should add to it 12 quarts of strong spirits (brandy), and 15 quarts of good vinegar, to complete the acetous fermentation. With a graduation tub which has been used, this addition of vinegar is unnecessary.

"The following simpler prescription for making sugar vinegar deserves attention. For every gallon of hot water take 18 ounces of sugar; and when the syrup has cooled to 75°, add 4 per cent., by measure, of yeast. When the vinous fermentation is pretty well advanced, in the course of 2 or 3 days, rack off the clear wash from the lees into a proper cask, and add 1 ounce of wine-stone, and 1 of crushed raisins, for every gallon of water. Expose it in a proper manner, and for a proper time, to the acetifying process; and then rack off the vinegar, and fine it upon beech chips. It should be afterwards put into bottles, which are to be well corked."

Where syrup, honey, or molasses are used, a little larger quantity must be employed than for sugar in the above processes.

c. *Grain.* Syn. Malt-vinegar. Ger. Malz-Getreide- oder Bieressig.

"The greater part of British vinegar is made from malt, by the following process:—1 boll of good barley malt, properly crushed, is to be mashed with water at 160° Fahr. The first water should have that temperature; the second must be hotter than 160°, and the third water, for the extraction of all the soluble matter, may be boiling hot. Upon the whole, not more than 100 gallons of wort should be extracted. After the liquor has cooled to 75° Fahr., 3 or 4 gallons of beer-yeast are poured in, and well mixed with a proper stirrer. In 36 or 40 hours, according to the temperature of the air, and the fermenting quality of the

wash, it is racked off into casks, which are laid upon their sides in the fermenting apartment of the vinegar work, which should be kept at a temperature of 70° at least, in summer partly by the heat of the sun, but in general by the agency of proper stoves or open fires. The bung-holes should be left open, and the casks should not be full, in order that the air may act over an extensive surface of the liquor. It would be proper to secure a freer circulation to the air, by boring a hole in each end of the cask near its upper edge. As the liquor, by evaporation, would be generally a few degrees colder than the air of the apartment, a circulation of air would be established in at the bung-hole, and out by the end holes. By the ordinary methods, three months are required to make this vinegar marketable, or fit for the manufacture of sugar of lead.

"In making vinegar for domestic purposes, the casks are usually set on their ends; and they have, sometimes, a false bottom, pierced with holes, placed about a foot above the true one. On this bottom, a quantity of *rape*, or the refuse raisins, &c., from the making of British wines, is laid. The malt liquor has a proper quantity of yeast added to it. In about 24 hours it becomes warm, and is then racked off into another similar cask. After some time, this racking process is discontinued, and the vinegar is allowed to complete its fermentation quietly. The proper temperature must always be kept up, by placing the cask in a warm situation."

4. *Acetic acid from the dry distillation of wood.* Syn. Pyroligneous acid, Wood-vinegar. Ger. Holzsäure, Holzessig. Fr. Vinaigre de bois, Acide pyroxylique.

The products of the dry distillation of wood being more fully discussed in connection under *Woon, destructive distillation of*, we shall here confine ourselves to one of the products, the acetic acid and its purification, in order to exhibit the comparative properties of this and other vinegars, all being employed in the arts for similar purposes.

a. *Prep.* When wood is subjected to a high heat in close vessels, it suffers a catalytic change among its elements, new compounds being formed, both volatile and fixed, the latter generally remaining and the former partly passing off as gas or condensing into liquids. For the fixed, see *CHARCOAL, LAMPHLACK, &c.*; for the gaseous matter, see *GAS, illuminating*; the liquids are of complex constitution, and will be found some under the general article of *WOOD* above referred to, others under *TAR, CREOSOTE, EMPYREMATIC OIL, &c.*, all of which are contained with vinegar in the condensed vapors. The following apparatus, which is an improvement on some of the older methods, is specially adapted to the production of acetic acid rather than for tar or charcoal, although these are important residuary products.

"The apparatus represented in Pl. II. figs. 8, 9, is convenient for the manufacture of pyroligneous acid. Fig. 1 shows the furnace in a horizontal section drawn through the middle of the flue which leads to the chimney. Fig. 2 is a vertical section taken in the dotted line x, x, of Fig. 1. The chest *a* is constructed with cast-iron plates bolted together, and has a

capacity of 100 cubic feet. The wood is introduced into it through the opening *b*, in the cover, for which purpose it is cleft into billets of moderate length. The chest is heated from the subjacent grate *c*, upon which the fuel is laid, through the fire-door *d*. The flame ascends spirally through the flues *e*, *e*, round the chest, which terminate in the chimney *f*. An iron pipe *g* conveys the vapors and gaseous products from the iron chest to the condenser. This consists of a series of pipes laid zigzag over each other, which rest upon a framework of wood. The condensing tubes are enclosed in larger pipes *i*, *i*; a stream of cold water being caused to circulate in the interstitial spaces between them. The water passes down from a trough *k*, through a conducting tube *l*, enters the lowest cylindrical case at *m*, flows thence along the series of jackets *i*, *i*, being transmitted from the one row to the next above it, by the junction tubes *o*, *o*, *o*, till at *p* it runs off in a boiling-hot state. The vapors proceeding downwards in an opposite direction to the cooling stream of water, are condensed into the liquid state, and pass off at *q*, through a discharge pipe, into the first close receiver *r*, while the combustible gases flow off through the tube *s*, which is provided with a stopcock to regulate the magnitude of their flame under the chest. As soon as the distillation is fully set agoing, the stopcock upon the gas-pipe is opened; and after it is finished, it must be shut. The fire should be supplied with fuel at first, but after some time the gas generated keeps up the distilling heat. The charcoal is allowed to cool during 5 or 6 hours, and is then taken out through an aperture in the back of the chest, which corresponds to the opening *u*, Pl. I. fig. 1, in the brickwork of the furnace. About 60 per ct. of charcoal may be obtained from 100 feet of fir-wood, with a consumption of as much brush-wood for fuel."—*Schubarth. Ure.*

The usual process for distilling wood for pyroligneous acid is, to heat it in cast-iron cylinders, or retorts some 6 ft. in length by 4 ft. diameter, laid horizontally in brick-work, with their ends projecting a little, every 2 retorts being heated by one fire, the flame playing around them, and the under-surface being protected from the direct and too powerful action of the fire. They are heated through the day, suffered to cool during the night, and the distillation being complete, the mouth plates of the retorts are removed, the charcoal raked out into a cooling box, and the retorts again charged with wood, about 8 cwt. being allowed for each. The average product of the acid containing much empyreumatic matter, is 35 to 36 galls. per retort, of spec. grav. 1.025. As in the preceding method, the uncondensed gas is burned under the retorts, thereby diminishing the amount of fuel required.

One of the methods employed in France is similar to that first described, excepting that the retort is a short vertical cylinder instead of being square, and being movable, while one is distilling another is filling with wood.

When thoroughly dried wood is employed, the acid is stronger, for wood ordinarily con-

tains a large proportion of hygroscopic moisture. (See *FUEL* and *WOOD*.) This is first expelled, and as the temperature rises the combined water and carbon, &c., reacting, generate the acid water. The temperature should not be too high at first, but towards the close is raised to a full red heat, which drives over the last portions of acid; but at the same time, it is in the later stages that a large proportion of tarry matter passes over, and finally much carbo-hydrogen gas. By the color of the flame of this gas we may judge of the close of the process, being at first reddish-yellow, from volatilized carbonaceous matter, then bluish from the presence of carbonic oxide, and lastly white from purer carbo-hydrogen.

Stolze, in his excellent essay on this acid, has given the results of numerous experiments in reference to the quantities of acid, oil, and charcoal from different kinds of wood, taken in equal weights and equally dry. He found that 1 lb. yielded from 5½ to 7½ ounces of oil and acid, and that the difference was due to the presence of resin, albumen, gluten, gum, &c., and not to a difference in the fibre; for after extracting these various ingredients by water, alcohol, &c., a lb. of the purified wood invariably yielded 7½ ounces of acetic acid.

While the quantity of liquid acid from pure wood is the same, the strength varies materially, an ounce saturating from 25 to 55 grs. carb. potassa. The strongest acid is obtained from firm woods of slow growth in a dry soil next from those of more rapid growth in a dry soil; then those in moist grounds; lastly the weakest from pines and resinous trees, the last being inferior to all the others. The trunk gives a stronger acid than the branches, although, when purified, they yield the same quantities of liquid acid.

The table on next page, by Stolze, shows the quantities of acid and its strength, of empyreumatic oil and charcoal obtained from 1 lb. wood dried at 100°, and therefore retaining much uncombined water. Being European woods, the detailed proportions do not strictly apply to the U. S., but the object is to show the results in accordance with the statements above given.

b. Purification.—The acid and tarry matters are collected in a cistern, the latter gradually separating to the bottom from which it is pumped off, and the former clearer liquid being run off from the top into the acid reservoir.

By a careful regulation of heat, the clear liquor may be distilled in a copper still, $\frac{2}{3}$ passing over perfectly clear, then $\frac{1}{3}$ of a yellow color, but with a strong heat it is yellow from the commencement, unless a small quantity of charcoal be employed. The first portions are weaker, containing acetone, some acid, &c.; the latter are much stronger, and a considerable quantity remains with the pitchy matter in the still. Repeated distillation does not purify it entirely, and even that which appears colorless becomes yellow and brownish after exposure to the air, from an alteration of the pyroresin which it contains.

Pyroligneous acid is usually employed in a

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Table of Pyroligneous Acid, Empyreumatic Oil and Charcoal, by Stolze.

Woods.	Weight of Acid.	1 oz. acid neutralizes of pure Carb. Potassa.	Weight of Empyreum. Oil.	Weight of Char- coal.	Botanical Names.
	Ounces.	Grains.	Ounces.	Ounces.	
White Birch.....	7 $\frac{1}{8}$	55	1 $\frac{3}{8}$	3 $\frac{7}{8}$	Betula alba.
Red Beech	7	54	1 $\frac{1}{2}$	3 $\frac{7}{8}$ +	Fagus sylvatica
Linden, large-leaved	6 $\frac{7}{8}$	52	1 $\frac{7}{8}$ +	3 $\frac{5}{8}$	Tilia plataphylla.
Oak.....	6 $\frac{7}{8}$	50	1 $\frac{1}{2}$	4 $\frac{1}{8}$	Quercus Robur.
Common Ash	7 $\frac{1}{2}$	44	1 $\frac{3}{8}$	3 $\frac{3}{4}$ +	Fraxinus excelsior.
Horse Chestnut....	7 $\frac{5}{8}$ +	41	1 $\frac{5}{8}$	3 $\frac{1}{2}$	Æsculus Hippocastanum.
Lombardy Poplar...	7 $\frac{3}{8}$ +	40	1 $\frac{3}{8}$	3 $\frac{3}{4}$ +	Populus dilatata.
White Poplar.....	7 $\frac{3}{8}$	39	1 $\frac{1}{4}$	3 $\frac{3}{4}$	Populus alba (abele.)
Bird Cherry	7	37	1 $\frac{1}{4}$ +	3 $\frac{1}{2}$ —	Prunus Padus.
Basket Willow	7 $\frac{3}{8}$	35	1 $\frac{1}{2}$ +	3 $\frac{1}{2}$ +	Salix (several species.)
Buckthorn	7 $\frac{1}{2}$	34	1 $\frac{3}{8}$ +	3 $\frac{1}{2}$ +	Rhamnus.
Logwood.....	7 $\frac{1}{2}$	35	1 $\frac{1}{2}$ —	2 —	Hamatoxylon Campechianum.
Alder	7 $\frac{3}{8}$	30	1 $\frac{1}{2}$ +	3 $\frac{1}{2}$	Alnus.
Juniper	7 $\frac{1}{4}$	29	1 $\frac{1}{2}$	3 $\frac{5}{8}$	Juniperus communis.
White Fir.....	6 $\frac{5}{8}$	29	2 $\frac{1}{8}$ +	3 $\frac{3}{8}$ +	Pinus Abies.
Common Pine.....	6 $\frac{3}{4}$	28	1 $\frac{1}{2}$	3 $\frac{1}{2}$ —	Pinus sylvestris (Scotch fir.)
Common Savine....	7	27	1 $\frac{7}{8}$	3 $\frac{5}{8}$	Juniperus Sabina.
Red Fir.....	6 $\frac{3}{8}$	25	2 $\frac{1}{4}$ —	3 $\frac{1}{4}$	Abies pectinata (Pinus abies.)

concentrated state for making acetates, in dyeing, color-printing, &c., and is therefore both purified and concentrated by the same series of operations on a large scale, a process first pointed out by Mollerat, and still carried on with trifling variations.

The rectified crude acid is neutralized by carbonate of lime (chalk, limestone) and a little milk of lime, and small portions tested after effervescence has ceased, to ascertain its neutrality. Fresh portions of tar separate and are removed by skimming, when the foam subsides. The clear liquor is then evaporated till it attains 15° B. = spec. grav. 1.114, and while hot, a saturated solution of sulphate of soda (Glauber salt) added sufficient to decompose the acetate of lime, and finally a little carbonate of soda to remove the last portions of lime. Every 100 parts of carbonate of lime added (or every 160 pts. dry acetate of lime) require about 160 pts. dry sulphate of soda or 365 crystal. Glauber's salt. The mixture is well stirred, and then suffered to settle; it deposits sulphate of lime, and a double salt of sulphate of lime and sulphate of soda, while acetate of soda remains in solution. The liquid, evaporated in copper or lead vessels to the density 38° B. = spec. grav. 1.356, is suffered to settle for 12—24 hours, and the clear solution run into iron or earthen vessels to crystallise. After 3—5 days, the mother-water is run off from the crystals, evaporated to 30° B. to recrystallise, and the same operation is repeated until the power of crystallisation has ceased; the residue evaporated to dryness and calcined, yields carbonate of soda. The crystals are large and well-defined oblique rhombic prisms of a yellowish-brown color. (See Fig. 2.)

The crystals are next melted in shallow cast-iron boilers at a temperature of 500° F. at most, and constantly raked and stirred, much care being required to prevent the decomposi-

tion of the acetic acid. They first fuse in their water of crystallisation, which is gradually evaporated, and the tarry matter is thus either rendered insoluble by carbonization, or burned off. When the frothing ceases, the liquid is ladled out into moulds and digested with water, but the solution should not have a greater density than 15° B., or otherwise the carbonaceous matter will not settle. The clear liquor is evaporated to 28° B., crystallised, again evaporated and crystallised, and the residue employed to dissolve fresh portions of the fused salt. The loss by fusion and crystallisation amounting to some 6 to 8 pr. ct.; the above quantities yield about 160 parts of dry or 260 crystallised acetate of soda.

About 200 lbs. of cryst. acetate of soda are introduced into an iron or copper still, with a copper capital and worm, and 119 lbs. concentrated sulphuric acid poured over it. The heat developed by this decomposition being apt to decompose acetic acid, the oil of vitriol is usually added in successive portions; but by neglecting the small portion of acid decomposed, the whole may be poured on at once, and thus the acrid fumes be avoided by the workmen; in the latter case the acetate is gradually worked through the sulphuric acid. When the whole is thoroughly incorporated, the still is slightly heated, and the heat increased gradually towards the close of the operation; but the higher temperature invariably carries over a little empyreumatic oil, and hence the latter portions of acid should be kept distinct from the rest. The product is nearly 279 lbs. of acid of 7° B. (1.05), with a slight greenish tint from the presence of copper.

The acid for table use, or where required purer, is subjected to a 2d distillation in a copper still with a capital and worm of silver, glass, or porcelain, the 1st portion of 5° B. being reserved for another distillation, and the

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rest having a density 7° B. The last trace of empyreumatic matter is removed by digestion with animal charcoal.

There are several variations in the above processes for purifying wood-vinegar which deserve notice. The sulphate of soda is sometimes dissolved in due quantity in the crude acid, and the carbonate or milk of lime subsequently added, which gives a solution of acetate of soda of sufficient strength without evaporation. Instead of the double decomposition of acetate of lime by sulphate of soda, some manu-

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facturers neutralize the crude or rectified vinegar directly by crude soda or sulphuret of sodium, which is believed to be more economical by the saving of time and fuel. Strong acid is also prepared by drying and gently torrefying the acetate of lime, and decomposing it in iron cylinders by sulphuric acid, similar to the process for muriatic acid. 208 pts. acetate of lime, and 133 pts. oil of vitriol give 270 acetic acid of the density 7° B. (1.05), but it is much more contaminated with empyreumatic oil.

5. Preparation and Properties of the Hydrate of Acetic Acid.

Formula of the dry acid $C_4H_3O_3$ ($\bar{A}$), of the hydrate $C_4H_3O_3 + HO$, or $\bar{A}$, aq.

Composition in equivalents.	Form.	H = 1	O = 100	Dry.	Hydrate.
4 eq. carbon.....	4 C	24	300.48	47.54	40
3 " hydrogen.....	3 H	3	37.50	5.82	5
3 " oxygen.....	3 O	24	300.00	46.64	40
1 " dry acid.....		51	637.98	100.00	
1 " water.....	HO	9	112.50		15
1 " hydrate of acetic acid.....		60	750.48		100

The dry acid does not exist in a free state, being always combined with water or a base; the least quantity of water united with it being 1 eq. as expressed in the preceding formula.

Hydrated Acetic Acid. Chem. Syn. Acidum aceticum glaciale, Glacial acetic acid, Radical vinegar. Ger. Essigsäurehydrat, Radikalessig. Fr. Acide acétique cristallisable, Vinaigre radical.

For the strongest and pure acid, the acetate of soda twice fused and crystallised after each fusion is thoroughly dried at 100—120° and powdered, and to every 3 lbs. in the retort is added gradually 9.7 lbs. of concentrated sulphuric acid, previously boiled to free it from water and nitrous acid, and cooled to 120°; $\frac{1}{8}$ passes over by the heat of the mixture alone. The retort should be kept warm by a cloth or paper cone over it, and a very gentle heat applied until the remainder is perfectly fluid. Without extreme care the acetic acid is decomposed and becomes empyreumatic. If carefully distilled, the only impurity may be sulphurous acid, which is removed by digesting it with black oxide of manganese or bin oxide of lead, forming a sulphate of the oxide, and redistilling the clear liquid. The redistillation also frees it from sulphuric acid and sulphate of soda. The above quantity yields altogether 2 lbs. concentrated acid with 20 per ct. water, but the last $\frac{2}{3}$ are separately received and exposed in a closed vessel to a temperature of 40° or less. The hydrate of acetic acid crystallises and the more aqueous solution is poured off; by refusion and recrystallisation the pure hydrate is obtained.

Another method of preparing the hydrated acid is to decompose dry acetate of lead by sulphuric acid. The crystallised acetate is heated in an oil or metal bath (8 tin, 4 lead, 3 bismuth) not higher than 320°, and stirred till the fused mass concretes; when cold it is pulverized, the powder again heated to 320°, and stirred till the particles cease to accrete.

(Edinb. Pharm.) 30 pts. of this powder are gradually added to 8 pts. concentrated and pure sulphuric acid, and distilled at 320° till dry. It is purified like the preceding by lead or manganese and distillation. Its density is 1.063 to 65 and not above 1.0685, but may be obtained as pure hydrate as above.

The method formerly pursued for obtaining glacial acid was by distilling crystallised verdigris (see *Neutral Acetate of Copper*), 20 lbs. yielding 9 $\frac{7}{8}$ lbs. of a greenish acid of 8.5° B. (spec. grav. 1.0627), and 6 $\frac{1}{2}$ lbs. of a mixture of metallic and protoxide of copper and charcoal as the residue. By a redistillation, in which the first and weaker acid was rejected, 6 lbs. of acid were obtained of 9° B. containing a little acetone (see this), which imparted an agreeable aroma to it, and caused its use as aromatic vinegar (spirit of verdigris).

Prop. Crystallises below 62° F. in transparent, colorless, broad laminæ and tables; fuses above 62° to a clear liquid, of spec. grav. 1.063 (1.0635 Mohr.) with a peculiar, penetrating and agreeable odor, and a highly pungent and acid taste, blistering the skin. It fumes slightly in a moist atmosphere, attracting water from it; miscible in every proportion with water, alcohol, ether, and many essential oils; it dissolves resins and camphor. The liquid acid boils at 248°; the density of its vapor is 2278; it is inflammable, burning with a pale blue flame; the vapor passed through an iron tube at a low red heat is resolved into carbonic acid and ACETONE, at a higher heat carbohydrogen gas is also produced; and, at a still higher, it is wholly converted into inflammable gases, while carbon is deposited. Mingled with sulphuric acid it becomes brown and black, with the evolution of heat and sulphurous acid. Periodic acid decomposes it, producing formic acid, iodic acid, and free iodine. Chlorine does not decompose it in the dark, when cold; but when exposed to the sun-light the 3 eq. of hydrogen are removed by chlorine as chlorohy-

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dric acid, three more eq. of chlorine occupying their place, forming the CHLORACETIC ACID. (See this and also ACETULE.)

Diluted Hydrated Acetic Acid. By mixing the hydrated acid with successive portions of water, Mollerat discovered that its density increases up to a certain point, and by subsequent dilution decreases, as shown by the table in the adjoining column.

By the table of composition of acetic acid given below, the hydrate, with a spec. grav. of 1.063, consists of 51 dry acid and 9 water; by the adjoining table the acid of density 1.0791 consists by calculation of 51 dry acid to 26.73 water; and the lowest of a density like the first (1.063) consists of 51 acid to 72.40.

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Hydrated Acid.	Water.	Sp. Gr.
110	0.0	1.0630
"	10.0	1.0742
"	22.5	1.0770
"	32.5	1.0761
"	43.0	1.0763
"	55.0	1.0742
"	66.5	1.0728
"	97.5	1.0658
"	108.5	1.0637
"	118.2	1.0630

The ratio in equivalents and density are more clearly shown in the following tabular view:

	Sp. Gr.	Equiv. Wt.	No. of Equiv.
		A aq.	A aq.
Hydrate of acetic acid.....	1.0630	51+9	1+1
Aqueous "	1.0791	51+26.73	1+3
" "	1.0630	51+72.40	1+8

It is therefore evident that with strong acid the spec. grav. is no test of the strength of the acid, since the same spec. grav. 1.063 belongs to two acids, the one containing 1 eq. and the other 8 eq. of water to 1 eq. of dry acid.

Testing the strength of acetic acid by the hy-

drometer may be relied on to a limited extent, where it is of good quality and does not contain mucilaginous matter.

Table by Mohr, showing the proportion of hydrated acetic acid in 100 parts of acid of different densities.

Hydr. Acid in 100 parts.	Beaumè.	Sp. Gr.	Hydr. Acid in 100 parts.	Beaumè.	Sp. Gr.	Hydr. Acid in 100 parts.	Beaumè.	Sp. Gr.
100	9°	1.0635	67		1.0690	34	6.6°	1.0450
97		1.0680	64		1.0680	31	6	1.0410
94	10°	1.0706	61		1.0670	28	5.6°	1.0380
91		1.0721	58		1.0660	25	5°	1.0340
88		1.0730	55	9°	1.0640	22	4.6°	1.0310
85		1.0730	52		1.0620	19	3.9°	1.0260
82		1.0730	49		1.0590	16	3.4°	1.0230
79	10.5°	1.0735	46	8°	1.0550	13	3.1°	1.0180
76		1.0730	43		1.0530	10	2.1°	1.0150
73		1.0720	40		1.0513	7	1.7°	1.0107
70	10°	1.0700	37	7°	1.0480	4	1°	1.0050

It may be remarked that the above table is not perfectly accurate, for the density of the liquid with 79 in the 100 (about 8 eq. water) has been found by others to be as high as 1.078—79. The best method of testing the strength of vinegar is to ascertain what quantity of alkali is neutralized by a given weight or measure of it, the carbonates of potassa and soda being used for that purpose. The usual way is to neutralize an ounce of the acid from a given weight of dry carbonate of potassa, either powdered or in solution, by weighing or measuring the balance to find how many grains have been used. Thus in the quick vinegar process an ounce of the acid usually neutralizes a little more than 30 grains of carb. potassa, when very strong as much as 60 grs. Good and strong wine vinegar neutralizes about 60 grs. The carbonates of potassa and soda, being ordinarily of different degrees of purity and liable to attract moisture from the air, cannot be regarded as certain tests of the strength, hence Dr. Ure proposes the crystallised bicarbonate of potassa, which is not liable to change in the atmosphere and is always

sufficiently pure. Its equivalent being 100.27 while that of dry acetic acid is 51, we may estimate every 2 grs. of it employed indicative of 1 gr. of dry acid, or by dissolving 200 in 100 measures of water, each measure used for neutralization indicates a grain of dry acid. Brande proposes to suspend by a thread a piece of weighed carbonate of lime (soft marble) in the acid, and after a short time to take it out, dry and weigh it. Its equiv. being 50.53 and that of the dry acid 51, each grain dissolved shows the presence of 1 gr. of dry acid. The chief difficulties in the use of marble are that it frequently contains a large proportion of carbonate of magnesia, which entirely changes its equivalent, and that weak vinegar will not readily act on it. Wagenmann, well known as having founded the quick vinegar process, has lately resorted again to the use of liquid ammonia, the strength of which is previously ascertained by sulphuric acid. Of all the methods, that of the bicarbonate of potassa is decidedly the best for ordinary use.

Tests of purity. The presence of salts and other fixed bodies is easily ascertained by

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evaporating to dryness, the acid being volatilizable without residue. Copper and lead are detected by the brownish color produced by sulphuretted hydrogen; sulphuric acid by nitrate or acetate of baryta, which precipitates a white insoluble sulphate of baryta; if a faint cloudiness is produced, the quantity of sulphuric acid is too small to be regarded, excepting in very weak acetic acid. The presence of empyreumatic oil is best ascertained by rubbing it on the hand until the acid evaporates, when the oil is recognised by its odor. Acid substances in vinegar are detected by the taste, particularly after neutralization by carbonate of soda. Common vinegars may be tested for all the above adulterations, excepting a little saline matter, which it avowedly contains, and is not to be regarded as an impurity.

Distilled Vinegar. Vinegar made from wine, malt, &c., containing many ingredients which render it objectionable for medical use, is frequently subjected to distillation in a copper still, with a solid tin, silver, glass, or porcelain capital, and with $\frac{1}{15}$ or less of coarsely-powdered charcoal, to obviate empyreumatic oil. A tinned capital is slightly attacked by the acid, a tinned copper still more, and hence silver is preferable. The first $\frac{1}{16}$ may be rejected, as often containing alcohol, or being too weak; the next $\frac{1}{8}$ are taken as pure distilled acid, and $\frac{1}{8}$ remains in the retort: 18—20 pts. of this acid (spec. grav. 1.010—1.015) neutralize 1 pt. of carbonate of potassa, while of a strong acid (spec. grav. 1.035—1.045) 2 pts. will neutralize 1 pt. of the carbonate.

Common Vinegars. Acetic acid prepared by the quick vinegar process from a good alcoholic liquid, by distillation of vinegars, or by the purification of wood vinegar, is usually colorless, or faintly colored, and has a sharp, acid, and rather agreeable taste, while that prepared by the slower fermentation of wine, cider, malt, molasses, honey, &c. is colored yellowish, or reddish yellow, from the coloring matters of those liquids, which are not destroyed by the vinous or acetous fermentation. Such common vinegars have a more or less sharp, acid taste, according to their strength, but exhibit at the same time an additional taste and flavor peculiar to each variety, arising from the presence of foreign substances. Thus malt-vinegar has generally a flat taste, and contains phosphates, gluten, mucilage, albumen, &c.; brandy vinegars contain often free alcohol, coloring matter, &c.; wine-vinegar, coloring matter, bitartrate of potassa (cream of tartar), &c., the latter giving it a peculiar taste, more agreeable than all others; and, lastly, cider-vinegar, containing malic acid, &c., which also imparts an agreeable taste and flavor. It is a common practice to assimilate purer vinegars by the quick process, or from wood to these common vinegars, to render them more palatable for domestic use, by adding a little cream of tartar for the taste, burned sugar or molasses for the color, and fine brandies or wines, or acetic ether, for the flavor (aroma, bouquet), nor when thus well manufactured can they be regarded as in any respect inferior to the finest wine or cider vine-

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gars. The spec. grav. of common vinegars varies from 1.010 to 1.030, equivalent to from 7 to 22 per ct. of hydrated acid.

Uses of Acetic Acid. Largely employed in the arts, in domestic economy, and in medicine.

In Medicine, the weaker acid is generally employed externally; the stronger is an excellent corrosive for warts and corns. It is used as a solvent for several drugs, and appears also to modify their action. The aromatic vinegar of the shops is a solution of camphor and essential oils in the hydrated acid: the salt of vinegar (sel de vinagre), is sulphate of soda moistened with the above. A superior aromatic vinegar is made by dissolving in 1 ounce of hydrated acetic acid, oils of cloves, lavender, and lemons, each 40 grains; of oils of bergamot and thyme, each 20 grs.; and 10 drops of oil cassia.

In Domestic Economy it is extensively employed as a condiment, and from its antiseptic properties preserves animal and vegetable substances which are subject to decay. The pyroligneous acid is preferable for many purposes, being more powerfully antiseptic from the presence of creosote among its empyreumatic matter, which likewise imparts an agreeable smoky flavor to meats prepared with it. Common weak vinegars are frequently strengthened by freezing, and removing the successive layers of ice; but although water is thus chiefly removed, the ice encloses so large a proportion of vinegar, that with a weak acid the process is by no means economical. Another process is to keep it heated in a porcelain or salt-glazed stoneware or enamelled iron vessel to any point between 212° and 220°; for while water boils at 212°, the hydrated acetic acid boils at 247—248°, so that at 212° a very large proportion of water evaporates with but little acid.

A peculiar fly collects in vinegar establishments, the *musca cellaris*; and a peculiar infusory animal, *vibrio aceti*, resembling an eel, is of frequent occurrence in vinegar, and may often be seen by the naked eye. These latter may be readily destroyed and removed by heating the vinegar to 212°, letting it settle, and decanting or straining it. Where vinegar is kept in open vessels, a gelatinous substance gradually collects in it, called mother of vinegar, which being produced at the expense of the acid, constantly renders the vinegar weaker. It is not generated in strong vinegar, but seems to form in direct proportion to its weakness.

Some cautions may well be given in reference to the vessels in which vinegar is employed in domestic economy, since they often consist of metals or metallic oxides. A painted vessel should never be employed, since the basis of nearly all pigments is white lead, which readily dissolves in acetic acid, forming sugar of lead; and many paints contain compounds of copper and other substances soluble in acetic acid, all of which may prove poisonous. Copper vessels may be employed with safety, provided the inner surface be kept bright, and the acid be not suffered to remain in them after cooling. Iron is too easily attacked by acetic acid to be used, for although the salt which is formed in the liquid, the ace-

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tate of iron, is not injurious in small quantity, yet it communicates a disagreeable styptic taste to any food which may contain it. Common earthen vessels glazed with oxide of lead (litharge, red-lead), part of which is frequently uncombined with the body of the ware, should not be employed, since the acid would undoubtedly dissolve that portion of the oxide, and may even attack the well-burned glazing itself—the more so if the acid be heated in the vessel. Salt-glazed stoneware, good English pottery, porcelain, glazed or enamelled iron, silver and copper (under the above precautions), may all be employed for boiling acetic acid, or its preparations, with safety.

In the *Arts*, acetic acid is largely employed; the more concentrated (not glacial) for making the acetates (see above), chiefly for the dyer and color-printer, the impure pyroligneous being often preferred, from its preventing the

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higher oxidation of a lower oxide (see *Iron-Liquor*, under *Acetate of Iron*). It is further used largely in the manufacture of white lead.

Statistics. The quantity of vinegar made in Great Britain amounts to about 2,800,000 galls. annually; all of which, excepting 100,000 galls., is made in England. It is difficult to estimate the amount made in the United States: 66,714 galls., valued at \$10,083, were imported in the years 1837–8; of which 9535 galls. (= \$3216), and \$5241 worth of domestic make, were exported in the same year. It is likewise difficult to estimate the amounts of acetates of lead and iron made in the United States. The importation of sugar of lead in 1837–8 was 203,626 lbs., value \$17,674; export, none.

ACETIC ETHER. Syn. Acetate of oxide of ethule. *Ger.* Essigsäures Aethyloxyd, Essigäther, Essignaphtha. *Fr.* Éther acétique.

Empir. formula $C_8H_8O_4$. Rational formula $C_4H_5O + C_4H_3O_3$, or $AeO, \bar{A}$

Composition by equivalents.

	H = 1	O = 100	Calc'd in 100 pts.	Found in 100 pts.	
				Dumas.	Liebig.
8 eq. carbon..... C_8	48	600.96	54.55	54.820	54.47
8 " hydrogen..... H_8	8	100.00	9.09	8.755	9.67
4 " oxygen..... O_4	32	400.00	36.36	36.426	35.86
	88	1100.96	100.00	100.001	100.00
or 1 eq. acetic acid..... $C_4H_3O_3$	51	637.98	57.91		
1 " oxide of ethule..... C_4H_5O	37	462.98	42.09		
	88	1100.96	100.00		

It is remarkable for being isomeric with aldehyde, their per ct. composition being the same; but the spec. grav. of the vapor of acetic ether = 3063, is double that of aldehyde = 1531. (*Kane*.)

Formation. Forms in greater or less quantity wherever alcohol is exposed to the action of oxygen, as in the process for acetal or acetic acid by platinum-black (see above); or where nascent acetic acid is in contact with alcohol, by the decomposition of acetate of potassa in alcohol by carbonic acid, or by the action of chlorine or bromine on spirit of wine. Formerly made by distilling concentrated acetic acid and alcohol, which is a tedious process, and may also be formed by distilling ethero-sulphate (sulphovinate) of potassa, with concentrated acetic acid in a water bath.

Prep. Distil 16 pts. of dry acetate of lead, $4\frac{1}{2}$ alcohol, and 6 concentrated sulphuric acid, or 10 crystallised acetate of soda, 6 alcohol, of 80–85 per ct., and 15 sulphuric acid. The acid is mingled with the alcohol, and, when cooled, poured upon the finely-powdered salt in the retort; the heat, at first gentle, is much increased towards the close, and the receiver thoroughly cooled. Common ether passes over with the first portions. The theory of the decomposition is, that ethero-sulphuric acid (or bisulphate of the oxide of ethule) is produced, which by mutual decomposition with the acetate of soda or lead, results in bisulphate of soda, or sulphate of lead and acetate of oxide of ethule.

The product is mixed with slaked lime in a

retort as long as it has an acid reaction, then with an equal volume of chloride of calcium, and after some hours distilled in a water bath. The ether obtained equals the weight of alcohol employed. To remove every trace of alcohol it is again digested with chloride of calcium, poured off, and redistilled.

Prop. A colorless, mobile liquid, of an agreeable, very refreshing odor, and a pleasant, burning taste; easily inflammable, with a yellowish flame and an acid odor; boils at 165° ; spec. grav. 0.89 at 60° ; spec. grav. of vapor 3.06. When pure it keeps unchanged, but the presence of water or spirit of wine gradually renders it acid. Dissolves in 7 pts. water, miscible with alcohol and ether in every proportion. Repeatedly shaken with chloride of calcium, it unites with a certain quantity, congealing to a white crystalline paste, from which water again separates the ether. Very readily decomposed by alkalis, its watery solution distilled with lime or potassa is resolved into acetic acid, which unites with the base, and alcohol passes over. With sulphuric acid it is resolved into ether and acetic acid. Chlorohydric acid forms with it chloride of ethule (or chlorohydric ether); nitric acid, nitric ether; acetic acid being set free. It dissolves essential oils, many resins, and in general to them, sulphur, phosphorus, &c., it acts similarly to ether.

Its purity may be known from the above properties, moreover, it should neither redden litmus nor be colored by sulphuretted hydrogen.

Uses. It is a constituent of several remedies

employed in Europe, such as the spiritus aceto-æthereus (1 pt. acetic ether + 3 pts. spirit of wine), and tinctura ferri acetici æthereæ (1 acet. ether + 2 spt. wine + 9 peracetate of iron). From its power of dissolving resins and essential oils, it might be employed in the preparation of varnishes.

ACETOMETER. *Tech.* An instrument or apparatus for measuring the strength of acetic acid. The methods of testing its strength are pointed out towards the close of the article on acetic acid, which see.

ACETONE. This being one of the most common and important of the products arising from the decomposition of acetic and other acids, the acetates, I propose giving the various products of this decomposition under the present article in a connected series, chiefly drawn from Liebig and Kane, who have been the latest and most successful in investigating this difficult subject.

The decomposition of the acetates with arsenious acid will be found under **CAOUDLE**. I shall describe, 1. Acetone; 2. The products of its decomposition with the oxy-acids; 3. The products from the halogens.

When the vapor of hydrated acetic acid is passed through a red-hot tube of porcelain or iron, it is entirely resolved, without deposition of carbon, into a volatile, inflammable liquid, acetone, and a mixture of carburetted hydrogen, carbonic oxide, and carbonic acid gases. If the heat go beyond a dull red, the acid is resolved into a brown empyreumatic oil and inflammable gases, with deposition of carbon.

Acetates, the bases of which retain carbonic acid at a red heat, produce, when heated in close vessels, the carbonate of the base and acetone. This takes place, for example, with the acetates of potassa, soda, and baryta. Where the oxide cannot retain carbonic acid at a red heat, as in the case of acetates of magnesia, zinc, or manganese, the acetone is accompanied by carbonic acid. If the oxide be easily reducible, as in the acetates of copper, silver, and mercury, there are given off hydrated acetic acid, carbonic oxide, carbonic acid, water, and acetone, and there is left a mixture of the metal with carbon in a minute state of division.

Neutral acetate of lead, melted at 365°, solidifies after a time, into a white crystalline frothy mass of sesquibasic acetate of lead, while one-third of the acetic acid is expelled in the form of carbonic acid and acetone. (*Liebig.*)

1. *Acetone.* Syn. Pyroacetic spirit (mesitic alcohol, bihydrate of mesitylene, *Kane*). *Ger.* Essiggeist, Essigalkohol. *Fr.* L'esprit pyroacétique.

Formula, C_3H_3O .

Its formation shown above may be rendered more clear by adding 1 equivalent of carbonic acid to 1 eq. of acetone, which will give an eq. of dry acetic acid.

C_3H_3O	1 eq. acetone.
$C \quad O_2$	1 " carb. acid.
$C_4H_3O_3$	1 " anhydrous acetic acid.

It is farther formed by the dry distillation of sugar, citric acid, &c.

Prep. By passing the vapors of concentrated acetic acid through a tube at a low red heat, or by the dry distillation of acetate of lime or lead. The liquid is then rectified over quicklime in a water bath till its boiling point is constant (132°), which removes acetic acid, pyroresin, &c. The receiver should be well cooled with ice.

Prop. It forms a clear, colorless, mobile liquid, of a peculiar, penetrating, somewhat empyreumatic odor, bearing a distant resemblance to acetic ether. Its spec. grav. is 0.7922 in the liquid form; 2022 in the form of vapor. It boils at 132°. Acetone has a pungent taste, resembling that of peppermint; and is miscible with water, alcohol, and ether in all proportions; it separates from its aqueous solution, when mingled with potassa, chloride of calcium, and other salts not soluble in acetone. In contact with caustic alkalies and air, acetone absorbs oxygen with rapidity; and produces, among other products not examined, a brown, resinous substance. Heated with chloride of lime, it yields carbonic acid and chloride of formate. See **FORMULE**. It is also decomposed by chlorine and oil of vitriol. It is inflammable, and burns with a clear, luminous flame.

In the preparation of acetone, particularly from salts of pyroigneous acid, there is obtained, in variable quantity, an oily liquid, much less volatile than acetone, which remains in the retort when the impure acetone is rectified. It is brown when impure, colorless when pure, has a disagreeable, empyreumatic odor, and a burning taste, boils at 248°, the spec. grav. of its vapor is 5204. Its formula is $C_{10}H_8O$. Kane, who described and analyzed this oil, has given it the name of Dumasine, out of compliment to M. Dumas. It is to be hoped that this principle of nomenclature may not be followed in chemistry. (*Gregory.*)

The chemical nature and constitution of acetone are still doubtful. It contains the elements of 1 eq. carbonate of oxide of ethule and 1 eq. hyduret of acetule = $C_6H_9O_3$; or of 1 eq. acetate of oxide of ethule and 1 eq. hyduret of acetule (olefiant gas) = $C_{12}H_{12}O_4$. According to Kane, it has a constitution similar to that of alcohol, and is the hydrate of the oxide of an organic radical, $C_6H_5 = (C_6H_5)O + HO = C_6H_6O_2$, which radical he calls *Mesitule*.

By distilling acetone with fuming sulphuric acid, Kane obtained, along with a number of other products, a substance, the formula of which he states to be C_6H_4 . (His analysis rather leads to the formula $C_{12}H_9$.) To this substance he has given the name of *Mesitylene*.

By the action of perchloride of phosphorus on acetone, Kane obtained a compound C_6H_5Cl , chloride of *mesitule*, which, by the action of a solution of caustic potassa, yielded chloride of potassium and the compound C_6H_5O , oxide of *mesitule*, differing from acetone as ether does from alcohol, namely, by 1 eq. less of water. By saturating a mixture of acetone and fuming sulphuric acid with lime and other bases, peculiar salts were obtained, containing the ele

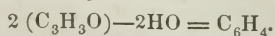
ments of sulphuric acid, oxide of mesitule, and a metallic oxide. These salts, according to Kane, are analogous to the sulphovinates (double sulphates of oxide of ethule and bases); but the theoretical views of Kane concerning these compounds do not appear to express their true nature.

That view which considers alcohol as the hydrate of an organic oxide of basic properties derives its chief support from the fact, that the oxide of ethule, when separated from its compounds, possesses the property of combining with water, and reproducing alcohol. But we cannot reproduce acetone from any of the compounds described by Kane, and which, according to him, contain the oxide of mesitule. Ether (oxide of ethule) is an oxide, because it combines with acids, equiv. to equivalent, and forms double salts, in which one equiv. of acid is neutralized by the ether, another by a metallic oxide. Now, neither acetone nor oxide of mesitule form similar compounds. In the compound of Kane's oxide of mesitule with sulphuric acid, the acid retains its capacity of saturation unimpaired, and 2 eq. of sulphuric acid neutralize 2 eq. metallic oxide. Consequently, the oxide of mesitule does not exist in this compound as a base, but in the same state as benzoic acid in the hyposulphobenzoic acid. Moreover, Frémy has described a substance, *Metacetone*, which has the same composition as Kane's oxide of mesitule, but very different properties. We know nothing of the real relation between those two substances and acetone.

Without, therefore, adopting Kane's theoretical views, we shall briefly describe the substances formed by him, under the names he has given them.

Mesitylene. Formula, C_6H_4 . (Kane, *Plantamour*.) *Prep.* Acetone is distilled with half its volume of fuming sulphuric acid. On the surface of the distilled liquid, which contains much acetic acid, swims a yellowish oil, which is washed with water and then rectified. As the first portions contain acetone, it is again heated in the water-bath, which expels the acetone. Mesitylene, when pure, boils at 275° . When the temperature, during the rectifications, rises higher than this, it is owing to the presence of another substance, resembling mesitylene, but less volatile.

Prop. Mesitylene is an oily, colorless liquid, has a faint and somewhat alliaceous smell. By the action of sulphuric acid on the less volatile portion of the products of the distillation of caoutchouc, an oil is obtained, which in all external properties is identical with Kane's mesitylene. (Gregory.) It is lighter than water, inflammable, and burns with a white smoky flame. Alkalies do not act on it; sulphuric acid, nitric acid, and chlorine act on it as they do on benzole. According to its formula, it contains the elements of 2 eq. acetone, minus 2 water, which explains its formation.



Kane obtained as the average of 3 analyses, carbon 89.602, hydrogen 10.41, whereas the formula C_6H_4 would require C 90.19 + H, 9.81.

Oxide of Mesitule (Mesitic ether). Formula,

C_6H_5O . (Kane.) Obtained by acting on an alcoholic solution of chloride of mesitule by caustic potassa until alkaline reaction is perceptible, and then adding 6 or 8 times its volume of water. An oily liquid separates, which is decanted, dried by contact with chloride of calcium, and rectified. It is a colorless liquid, having an aromatic odor like that of peppermint. It boils at 248° , is inflammable, burning with a very brilliant flame and much smoke.

Chloride of Mesitule (chloromesitic ether, Kane). This compound cannot be obtained by the action of hydrochloric acid either on acetone or on the preceding substance. Its formula, according to Kane, is C_6H_5Cl ; but, of several analyses, one only gave results approximating to theory, viz. C 47.27 + H 6.76 + Cl 45.88. Its composition cannot, therefore, be considered as fully ascertained. To obtain it, 2 parts of perchloride of phosphorus are added by degrees to 1 part of acetone, the mixture being surrounded by cold water, and 3—4 times its volume of water added, when the chloride of mesitule separates. It is washed with a little water, and chloride of calcium put in it to purify it. It is an oily liquid, heavier than water, and convertible by heat into hydrochloric acid and mesitylene, so that it would seem that the chlorine in this compound cannot be replaced by oxygen.

Iodide of Mesitule is obtained by the distillation of a mixture of iodine, phosphorus, and acetone; but never in a state of purity. It seems to be analogous to the chloride. The residue of the distillation contains hypophospho-mesitulous acid, and another compound containing iodine, in golden-yellow scales, which Kane calls Iodide or Pteyle. (See below.)

Chloroplatinate of Oxide of Mesitule. Discovered by Zeise, who called it *Metacechlorplatin*.

Formula, $C_6H_5O + PtCl$.

Prep. 1 pt. bichloride of platinum dissolved in $2\frac{1}{2}$ pts. acetone by digestion and cohobation yield chlorohydric acid and an ethereal liquid, which distil over, and an acid brownish residue, which contains the chloroplatinate and resinous or tarry matter. This is well washed with water, which leaves a brown pitchy substance, Zeise's platinum-resin.

The chloroplatinate is purified by repeated crystallisations, first in acetone acidulated with hydrochloric acid, afterwards in pure acetone. It forms small sulphur-yellow indeterminate crystals, nearly inodorous, not altered by a heat of 212° , or in vacuo, but decomposed by a higher temperature, when it burns with a green flame, and leaves silver-white metallic platinum. It is sparingly soluble in water, with a yellow color, and slightly in alcohol, insoluble in ether; its aqueous solution is decomposed by boiling. When the mother-liquid of these crystals is heated, gas is disengaged, and while the liquid becomes clear and colorless, a flocculent black powder is deposited which explodes when heated. Zeise calls it *Pyracechlorplatin*. The platinum-resin is brittle, of a glassy fracture, pulverizable, soft and plastic when heated, burns with flame, leaving platinum; it is wholly soluble in a solution of potassa and

in acetone, partially in ether and alcohol. Zeise terms it chloraceplatin.

2. *Action of the Oxyacides on Acetone.* a. *Sulphuric acid.* 1 acetone mixed with 2 by weight of fuming sulphuric acid, it becomes strongly heated and evolves sulphurous acid; by adding water and neutralizing by lime, baryta or oxide of lead; an insoluble sulphate is formed and a soluble salt of the base with sulphomesitolic acid. This acid has not been isolated, for upon separating the base, and evaporating the liquid, it becomes black, contains free sulphuric acid, and smells of sulphurous acid and oxide of mesitule. Its probable formula is $C_3H_3O + HO, SO_3$.

Sulphomesitulate of Lime. Formula $C_3H_3O + CaO, SO_3$. Obtained as above; very soluble in water, crystallising in fine crystals from a cooling, concentrated solution, with 7.2 per ct., or 1 eq. water; it loses $\frac{1}{2}$ eq. water by heat.

Sulphomesitulate of Baryta. Formula $C_3H_3O + BaO, SO_3$. Formed like the preceding by baryta instead of lime. Crystallises in small pearly tables. Both of these salts decomposed by heat leaving sulphates of lime or baryta.

When 1 measure of oil of vitriol and 2 measures of acetone are mingled, treated with water and neutralized by lime, a salt is obtained containing twice the quantity of acetone, with a formula $2(C_3H_3O) + CaO, SO_3$.

b. *Nitric Acid.* When 1 part of fuming nitric acid is mixed with 2 of acetone, a violent reaction takes place. When the reaction is moderated by cooling it, the addition of water causes the separation of a yellow oil, which consists of two different liquids, one of which is viscid, the other very fluid. The former predominates when the action has been very violent, the latter when it has been more moderate. Kane has given to the former the name of *Mesitule aldehyde*; to the latter, that of *Nitrite of oxide of pteyle*.

Nitrite of Oxide of Pteyle. Formula, C_6H_3O, NO_3 . It is heavier than water, and is decomposed by that liquid, dissolved by alkalis with a brown color. Paper impregnated with it burns like tinder. It withstands a heat of 212° ; but cannot be distilled without decomposition. When heated in a tube over the spirit-lamp, it explodes violently.

Mesitule Aldehyde. Formula, $C_6H_4O_2$. Prepared pure, by boiling mesitylene in nitric acid as long as reaction is perceived. It is a heavy, viscid, reddish-yellow liquid, of a sweetish penetrating odor, difficultly soluble in water; very soluble in alkalis, with a yellowish-brown color; it absorbs dry ammonia, forming with it a brown resin-like mass, which is soluble in water, and may be crystallised by careful evaporation. When the liquid is rendered slightly alkaline by potassa, nitrate of silver causes in it a precipitate, which, when heated in the liquid, is reduced to the metallic state. Kane considers this as a proof of the analogy of this substance to aldehyde; but the same effect is produced, in the same circumstances, by all soluble organic matters which are not acid. According to Kane, mesitule aldehyde is produced by the direct oxidation of mesitylene by the nitric acid, 2 eq. of oxygen being abstracted from the acid.

c. *Phosphoric Acid, Phosphomesitule acid.* Glacial phosphoric acid (metaphosphoric acid) is dissolved by acetone, with disengagement of heat, and production of a brown color. When the mixture is neutralized by bases, soluble salts are obtained.

The salt of soda crystallises in fine rhomboidal tables, which become opaque by efflorescence in the air; and, when heated, fuse in their water of crystallisation, becoming white, then black, and finally leaving a residue of 48.8 per ct. phosphate (pyrophosphate!) of soda. (Kane.)

Hypophospho-mesitule Acid. The residue of the distillation of a mixture of iodine, phosphorus, and acetone, with an excess of phosphorus, on cooling forms a mass like asbestos, of which water dissolves one portion, leaving another in yellow scales undissolved. The solution has a taste both acid and bitter; when neutralized with baryta, it forms an insoluble and a soluble salt, the latter congealing to a crystalline mass when its solution is evaporated. This mass is a mixture of iodide of barium and hypophospho-mesitule of baryta, from which boiling alcohol dissolves the iodide of barium, and leaves the new salt, which has solubility in water, and forms small white crystalline grains, without any reaction on vegetable colors. When heated, they burn with the flame of phosphorus, leaving a black residue, which by calcination is converted into phosphate of baryta. Heated with nitric acid, there is a violent reaction. Formula of the hypophospho-mesitule of baryta, according to Kane, $C_6H_3O_3P_2, BaO$. But he obtained by the action of nitric acid on it, 74 to 75 per ct. phosphate of baryta, containing 43.8 to 44 per ct. baryta, and indicating, not 2 eq. phosphorus to 1 eq. baryta, as in his formula, but 3 eq. phosphorus to 2 eq. baryta. According to Plantamour, this salt could not be obtained by Kane's process, and the subject evidently requires farther investigation, as shown also by Berzelius.

3. *Action of the Halogens on Acetone and Mesitylene.*

Mesitic Chloral. Formula, $C_6H_4Cl_2O_2$. (Dumas; Kane.) Calculated by the formula in 100 pts., it does not agree with a single analysis of it by Liebig. By calculation $C\ 28.86 + H = 3.13 + Cl\ 55.48 + O\ 12.53$, Liebig found $C\ 28. + H\ 2.8 + Cl\ 52.6 + O\ 16$. When dry chlorine gas is passed through acetone till all disengagement of hydrochloric acid has ceased, it is converted into a liquid insoluble in water, of a penetrating and offensive odor, with a spec. grav. of 1.33. It causes blisters on the skin; boils at 260° ; is then decomposed with disengagement of hydrochloric acid. It is not perceptibly acted on by alkalis, nor by oil of vitriol, at the ordinary temperature; but an excess of caustic potassa, with the aid of heat, dissolves it, producing chloride of potassium and a new acid, which forms soluble salts, with nearly all metallic oxides, but it has not been particularly examined.

Chloride of Pteyle. Formula, C_6H_3Cl . (Kane.) Formed by passing chlorine through mesitylene to saturation, when it congeals to a crystalline mass, from which boiling ether dissolves

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the solid product and deposits it again in crystals on cooling. When purified by recrystallisation, it resembles commercial sulphate of quinine; is insoluble in water; is not decomposed by potassa in its aqueous or alcoholic solution, sublimes at a very high temperature, and in dry ammonia without alteration. The analysis of this body gave results not exactly agreeing with the formula. It is remarkable that chlorine and nitric acid act differently on mesitylene.

Iodide of Pteyle. This name has been given by Kane to the yellow micaceous crystals obtained by resolution of the residue after distilling the mixture of iodine, phosphorus, and acetone. They resemble iodoform (iodide of formulæ) in all their properties, except that they are volatile nearly at a red heat, without decomposition. Their composition has not been ascertained.

The formulæ which have been given for the compounds just treated of, as products of the decomposition of acetone, must be considered as the expression of a theoretical view, founded on a supposed analogy between acetone and alcohol. Before we can come to any certain conclusions in regard to these compounds, they must all be subjected to a rigid investigation. (*Liebig's Turner and Organ. Chemie.*)

ACETOUS FERMENTATION. *Chem. Tech.* A change which many organic substances undergo spontaneously, under favorable circumstances, becoming wholly or in part dilute acetic acid. The operations, as conducted on a manufacturing scale, are fully given under **ACETIC ACID**, and we now propose to offer a few remarks of a more general character. The action of platinum-black was described, and the action of a ferment compared to it. It was observed by the earlier chemists, that carbonic acid was produced during acetous fermentation, but this arose from their examining fluids which had just undergone the vinous fermentation, or were still forming alcohol while other portions were entering on the acetous change. When carbonic acid is produced, it arises not from the oxidation of the alcohol, but of foreign matter in the alcoholic liquid (wine, beer, &c.). The acid is produced from the alcohol by the absorption of oxygen, which resolves it wholly into acetic acid and water. Saussure has shown that moistened earthy mould, vegetable substances, and seeds have the power of absorbing oxygen and hydrogen, and forming water, or oxygen alone, in the absence of hydrogen, and forming oxidized products. Hence the formation of acetic acid is similar to that of sulphuric, the organic matter (ferment) acts as a medium of conveying oxygen from the air to the alcohol, as the nitric oxide conveys oxygen from the air to the sulphurous acid. Moistened shavings and sawdust absorb oxygen from the air with great rapidity, and undergo putrefaction, giving off carbonic acid and being converted into a brownish soluble substance; moistened with dilute alcohol, the oxygen they absorb is passed over to the alcohol and acetic acid is produced without putrefaction. Wine and beer only become acid when they contain organic sub-

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stances capable of absorbing oxygen, for when the ferment by long-continued vinous fermentation is deposited and the clear wine racked off, it is little liable to become acetous; and beer subjected to very slow fermentation at a low temperature (*Ger. Untergährung*) likewise deposits its altered nitrogenous ferment in an insoluble state, and is not subject to the acetous change at common temperatures. (*Liebig.*) The above views of Liebig do not appear to me to be a sufficient explanation of all the facts, for where the moist organic substances are shown to absorb oxygen, they are themselves decomposed, but where moistened with dilute alcohol they are not, as is shown by the shavings after lengthened use in the quick vinegar process. Moreover, acetic acid itself, put into a pure alcoholic liquid, induces the acetous change. Mitscherlich ascribes the change of alcohol into acid to the contact of certain bodies; Berzelius calls the force catalysis. (See **CONTACT** and **CATALYSIS.**) Why should we, however, suppose that the cause or mode of the acetous change is always the same, when we have numberless examples in chemical changes of the same body resulting from very different processes. It is true, we may ascribe all the modes of generating acetic acid to contact, or catalysis, but some of them are more readily explained by Liebig's view of a transfer of oxygen. On the other hand, Liebig's view does not explain the change produced by acetic acid itself in alcohol, nor reconcile the opposite effects of a change in the transferring substance in one case and not in another. The acetous change produced by the acid itself in alcohol, is rather to be classed with that singular general observation, that where a substance has commenced a change it has a tendency to carry others with it. May it not be ascribed to a variety of affinity, which may be called *Inducting* or *Imparted Affinity*?

Where vinegar is exposed to the action of the air, there is gradually formed in it a kind of vegetation, a slippery, gelatinous, coherent mass, which is called *Mother of Vinegar*, from the prevalent idea that it is the cause of the formation of vinegar. While moist it is nearly transparent, and contains much vinegar, which is removed with difficulty, by pressure and washing. It gradually dries to a transparent yellowish, tasteless pellicle, which swells again in water, and more especially in acetic acid, nearly to its original bulk. When thus purified it has no effect whatever in promoting acetous fermentation, and when it does so act it is only by its content of acetic acid. Being formed out of the acid, it constantly tends to weaken the acid, and hence its formation should be avoided, by excluding the access of air as far as practicable.

Other vegetable substances, beside alcohol, are capable of undergoing the acetous fermentation without a perceptible previous formation of alcohol, and some, indeed, which are not known to be capable of the vinous fermentation. Sugar, by the addition of certain ferments may pass directly into acetic acid without an intermediate alcoholic change. Such a ferment is vegetable albumen, precipitated by

acetic acid from the expressed juice of potatoes, beets, &c. Acetic acid is also produced by the putrefaction of vegetable matter in marshy grounds. (*Berz.*) These changes have not been investigated and are of little practical importance since the acetous fermentation is always applied to alcoholic liquids.

The conditions most favorable to acetous fermentation, or in other words, to the absorption of oxygen by alcohol, are as extended a surface as possible, the free access of air and a proper temperature. The quantity of fresh air admitted should not be too great, for the formation and escape of aldehyde would diminish the quantity of acid. The temperature in the quick process should be 100° to 105°, but in the ordinary process such a temperature would create too great a loss by evaporation, and hence it should be in the latter case at from 70° to 80°.

When the fermentation has ceased, the vinegar should be racked off, or filtered from the lees, which would tend to induce the putrefactive fermentation, and injure or destroy a portion of the acid already formed.

ACETULE. *Chem.* It was shown in the commencement of **ACETIC ACID** that by the slower oxidation of alcohol there is first produced aldehyde and then acetic acid (see the formula of this change). By the action of nitric acid on alcohol, different quantities of oxygen are given to the elements of alcohol, which abstract hydrogen or carbon, the former rather than the latter in the early stages of oxidation, and sometimes replace it; the products of oxidation, being aldehyde, acetic, formic, oxalic, and carbonic acids, water, &c. More powerful oxidizing agents produce higher oxides of aldehyde, such as aldehydic and ace-

tic acids, and these again still higher, such as formic and carbonic acids.

When we examine aldehyde, and the aldehydic (lampic) and acetic acids, formed from it by oxidation, we find that they contain the same number of equivalents of carbon and hydrogen combined with different quantities of oxygen, and from this circumstance, as well as their mode of formation, we are led to infer that they are oxides of one and the same base, or radical, which is called Acetule. Although not isolated, yet we can trace this radical through manifold combinations. Liebig regards olefiant gas as a hyduret of acetule, and hence places its combinations in this series; I prefer, however, with Berzelius, regarding it as an independent radical, which he terms **ELAYL** (which see). I shall therefore exhibit the acetule-series, exclusive of elayl, describing its various combinations, and referring such as are either of great practical importance or of doubtful connection with acetule, to their alphabetical places in the work.

Acetule. Formula C_4H_3 . By the removal of 2 eq. of hydrogen from ethule, the radical acetule is produced. Aldehyde is regarded as the hydrate of the 1st oxide of this radical; lampic acid the 2d; and acetic acid the 3d; for aldehyde readily passes into acetic acid by receiving 2 eq. oxygen, and by removing 1 eq. of oxygen from the latter it is converted into lampic or aldehydic acid. Acetule differs, therefore, materially from ethule, for the oxide of the latter exhibits strong basic properties, while the former forms two decided acids, and even aldehyde (its hydrated oxide) shows feeble acid properties by forming a crystallisable compound with ammonia. Acetule and its oxidized compounds are the following:

Acetule.....	Ac	C_4H_3	} not isolated.
Oxide of acetule	AcO	C_4H_3O	
Hydrated oxide of acetule...	$AcO, aq.$	$C_4H_3O + HO$	aldehyde.
Acetulous acid.....	$AcO_2, aq.$	$C_4H_3O_2 + HO$	aldehydic (lampic) acid.
Acetulic acid	$AcO_3, aq.$	$C_4H_3O_3 + HO$	hydrate of acetic acid.

1. *Hydrated Oxide of Acetule.* Syn. *Aldehyde*, from *alcohol dehydrogenated*, signifying its mode of formation.

Formula, empirical $C_4H_4O_2$, rational $C_4H_3O + HO$ or $AcO, aq.$

Composition.	Form.	H = 1	O = 100	Calculated.	Found.
4 eq. carbon.....	C_4	24	300.48	55.024	54.711
4 " hydrogen.....	H_4	4	50.00	8.983	8.991
2 " oxygen.....	O_2	16	200.00	35.993	36.198
1 " aldehyde		44	550.48	100.000	99.000 <i>Liebig</i>

Theoretic view.	Form.	H = 1	O = 100	Calculated.
1 eq. acetule	C_4H_3	27	337.98	61.35
1 " oxygen.....	O	8	100.00	18.18
1 " water.....	HO	9	112.50	20.47
1 " hydrated oxide of acetule.....		44	550.48	100.00

Formation. Arises in many ways from the decomposition of alcohol and ether. By passing dry ether through a glass tube, at a low red heat, it is resolved into inflammable gases and aldehyde.

It is farther formed by the action of chlorine

and many chlorides on alcohol, and by platinum-black, when acetal is also formed.

Prep. Two parts of aldehydammonia are dissolved in 2 parts of water, and mixed with a cold diluted acid, made with 3 parts of oil of vitriol, and 4 parts of water. The mixture is

distilled in a retort, connected with a condenser surrounded by ice, with the heat of the water-bath. The product is twice rectified with its own bulk of chloride of calcium, at a temperature not exceeding from 77° to 86° , in order to free it from uncombined water.

Prop. A clear, colorless liquid, refracting light feebly, of a peculiar ethereal and suffocating smell. It boils at 71° , spec. grav. at 65° , 0.79. It is miscible with water, alcohol, and ether in all proportions, neutral to test-paper, inflammable, burning with a pale whitish flame. In contact with oxygen it absorbs it, and is converted into hydrated acetic acid; dissolves phosphorus, sulphur, and iodine; is decomposed by chlorine and bromine, forming hydracids and oily substances containing chlorine and bromine. Solution of chlorine converts it into acetic acid, and the same change takes place when it is heated with dilute sulphuric acid. When mixed with hydrate of sulphuric acid, it becomes thick and brown, and after some time a black carbonaceous coagulum separates. With dry ammonia it forms a crystallisable body, aldehyde ammonia. When mixed with an aqueous solution of potassa, the mixture soon becomes brown, and after some time a light brown resinous body rises to the surface. When a solution of aldehyde is warmed with oxide of silver, the oxide is partially reduced, without disengagement of gas, and the vessel is covered with a brilliant surface of silver. The liquid contains aldehyde of silver. A liquid containing aldehyde, to which some ammonia is first added, and then nitrate of silver, till all alkaline reaction disappears, produces, when heated, the same appearance of reduced metal without the solution of gas; and this, with the action of potassa, is a sure and simple method of proving the presence of aldehyde in any liquid. When long kept, aldehyde spontaneously changes into two substances of the same composition: one of which, metaldehyde, is solid at ordinary temperatures; the other, elaldehyde, is a liquid.

When potassium is introduced into aldehyde, heat is developed, hydrogen-gas is disengaged, and a solid compound is formed, containing potash, which is soluble in water, has an alkaline reaction, reduces the salts of silver with the aid of heat, and is decomposed by acids, without yielding aldehyde. This compound has not been minutely examined; it is probably aldehyde of potash, or contains that substance.

From the ease with which it may be formed from alcohol and from its great volatility (boiling at 71°), it will readily be seen what an important influence it exercises over the economy of the quick vinegar process.

Aldehydammonia. Döbereiner observed that raw acetal, saturated with ammonia, deposited a white crystalline body; in which Liebig proved the presence of aldehyde.

Formula, C_4H_3O, NH_3, HO , or AcO, NH_3 aq.

Prep. Six parts of sulphuric acid, mixed with 4 of water, 4 of alcohol of 80 p. c., and 6 of binocide of manganese in fine powder, are distilled at a gentle heat. The retort should be only $\frac{1}{2}$ filled, and connected, air-tight, with a

receiver cooled by ice to 32° . When no more frothing is observed in the retort, the product, which amounts to 6 parts, is rectified with its own weight of chloride of calcium. The product now amounts to 3 parts, and is again rectified with its own weight of chloride of calcium. In this way $1\frac{1}{2}$ parts are obtained of a liquid, consisting chiefly of aldehyde, with alcohol, a little water, and acetic and formic ethers. These $1\frac{1}{2}$ parts are mixed with their bulk of ether, and the mixture is saturated with dry ammoniacal gas, when crystals of aldehydammonia separate in abundance; which, when washed with ether and dried at the ordinary temperature, are quite pure.

Prop. Colorless, transparent, brilliant, acute rhombic prisms, refracting light powerfully, friable, having an odor of turpentine; fusible between 158° and 176° , distilling unchanged at 212° , distilled with access of air there is a resinous brown residuum. The crystals become brown by exposure to the air, and even in sealed tubes, and acquire a smell of burnt feathers. They may be kept for a short time under ether. They are very soluble in water, and the solution has an alkaline reaction; soluble in alcohol (better in warm), acetal, and acetic ether; nearly insoluble in ether, which precipitates them again slowly in large and distinct crystals from their saturated solution in alcohol, acetal, or acetic ether. A concentrated solution gives, with nitrate of silver, a precipitate soluble in water, insoluble in alcohol, which contains nitric acid, oxide of silver, ammonia, and aldehyde; by heating with water the oxide is reduced, and aldehyde set free.

Resin of Aldehyde. A product of the decomposition of the aqueous solution of aldehyde by caustic potassa. It is likewise produced when an alcoholic solution of potassa is exposed to the atmosphere, (and is often found upon dissolving in water potassa prepared by alcohol? J.C.B.) The reaction has not been fully studied, yet it is known that the resin of aldehyde is not the only product. A mixture of potassa with 4 pts. aldehyde, and 1 pt. water, when heated, gives off a combustible liquid, of a most penetrating spirituous odor, and smarting the eyes very powerfully; it is miscible with water, but its composition is unknown. The resin swims on the surface of the liquid in the retort, in the shape of a soft light-brown mass, very soluble in alcohol, and a solution of caustic potassa, from which it may be obtained by evaporation, or by saturating with an acid. When dried and heated to 212° , it gives off a very nauseous soapy smell, and it sometimes inflames spontaneously.

Elaldehyde. Discovered by Fehling. Empirical formula, $C_{12}H_{12}O_6$, (*Fehling*.) Isomeric, or rather polymeric with aldehyde. When pure aldehyde is long kept, it loses by degrees its solubility in water, and produces two new substances. If kept at 32° , it forms ice-like needles, which melt at about 35° into a transparent liquid, lighter than water. It has the odor of aldehyde, but weaker; it boils at 201.5° , its vapor being very inflammable with a blue flame. It does not become brown with potash, nor does it act on nitrate of silver; it does not combine with ammonia; with cold

oil of vitriol it becomes brown; when heated with it, it is blackened. Its composition by weight is exactly that of aldehyde, but the density of its vapor shows that 3 vol. of vapor of aldehyde have been condensed into one volume of elaldehyde.

Metaldehyde. When aldehyde is kept at the ordinary temperature in closed vessels, it is partially converted into crystals of metaldehyde, which sometimes disappear without our being able to detect them in the liquid. It forms long needles, or transparent, hard, four-sided prisms, easily pulverized, volatile at 230° without previous fusion. The vapor condenses in the air in the form of light, snowy floccula. It is insoluble in water, readily soluble in alcohol, from which it may be crystallised. It has also the same composition by weight as aldehyde; but the density of its vapor is probably very different, although not yet ascertained. (*Fehling.*)

2. *Acetulous Acid.* Syn. Aldehydic acid, Lampic acid. Formula of the hydrated acid $C_4H_3O_2 + HO$, or AcO_2 , aq. The name of aldehydic acid has been given to the acid which is formed when an aqueous solution of aldehyde is warmed with oxide of silver. In this case, as above mentioned, part of the oxide of silver is reduced, and the rest combines with the new acid. If a current of sulphuretted hydrogen be passed through the liquid, the silver is separated as sulphuret, and the aldehydic acid is obtained pure, but much diluted. It has a sharp acid taste, and neutralizes metallic oxides; but its salts cannot be obtained pure, because by the evaporation of those with an alkaline base, they pass into acetates, with the deposition of a dark-brown substance resembling the resin of aldehyde; evaporated in vacuo they are obtained of a yellow color. Their characteristic property is to yield with cold sulphuric acid a vapor which attacks the eyes strongly, while the mixture becomes black. If a solution of aldehydate of baryta be warmed with nitrate or oxide of silver, or of mercury, these metals are reduced without effervescence, and the solution is found to contain pure acetate of baryta. The following behavior leaves no doubt as to the composition of this acid:—

Aldehyde, gently warmed with oxide of silver, gives metallic silver and a soluble salt of oxide of silver, the latter of which may be safely assumed to contain 1 at. oxide of silver. If the solution of this salt be mixed with as much barytic water as precipitates all the oxide of silver, and the solution, which contains the newly formed salt of baryta, be heated along with the oxide of silver just formed, the latter is completely reduced, and the liquid now contains pure acetate of baryta.

In this salt the oxygen of the acid is to that of the base as 3 : 1, but 1 of these 3 at. of oxygen was combined with oxide of silver in the aldehydate, the salt first formed, and passed from the silver to the aldehydic acid, converting it into acetic acid. Now acetic acid in its dry salts has the formula $C_4H_3O_3$; consequently the dry aldehydic acid must have the formula $C_4H_3O_2$, or in the state of hydrate $C_4H_3O_2 + aq$.

Aldehydic acid is probably one of the ingredients of the so-called lampic acid, discovered by Davy and Faraday, and more closely but not sufficiently examined by Daniell and Connell. When a coil of fine platinum wire is kept red-hot in the wick of a spirit-lamp (see *Aphlogistic* under *LAMP*), and the products of this low combustion condensed in the head of an alembic, an acid liquid is obtained, the vapor of which acts strongly on the eyes, and which contains several acids, one of which is formic acid. (*Connell.*) The salts which Daniell obtained by neutralizing this acid liquid (lampic acid), with alkalies, approached nearly to the acetates in composition, but differed from them by their action on the salts of silver and mercury; the solutions of which, heated with the new salts, deposited reduced metal, with disengagement of carbonic acid gas, while part of the oxides was found dissolved in the form of acetates. This induced Connell to pronounce the lampic acid a mixture of acetic and formic acids: but the solutions of its alkaline salts become dark brown by evaporation, and the acid itself is blackened by heating with sulphuric acid; characters which do not belong to either acetic or formic acids, but rather to aldehydic acid. Besides, acetic and formic acids, although both have a pungent smell, do not affect the eyes, which the lampic and aldehydic acids do. Hence it is probable that lampic acid is a mixture of aldehydic, acetic, and formic acids, the 2d and 3d being products of the higher oxidation of the 1st and the 3d of the 2d. A comparison of the lampic acid with the aldehydic acid prepared directly from aldehyde, will soon decide the question.

3. *Acetule Acid.* See ACETIC ACID.

ACETULE COMPOUNDS, FORMED BY THE DECOMPOSITION OF ETHER AND ITS COMPOUNDS BY CHLORINE.

This interesting but complex subject has been investigated with great zeal and success by Malaguti, Liebig, Regnault, &c.; and while it is still *in transitu*, I shall here present a connected view of the series, drawn in part from the *Wörterbuch der Chemie*, by Liebig, Pogg., and Wöhler, &c. The following table exhibits the successive decompositions of chloride of ethule (chlorohydric ether) by chlorine, as shown chiefly by Regnault.

		Formula.	Density of vapor.	Spec. grav.	Boiling point.
	Chlorohydric ether (chloride of ethule)...	C_2H_5Cl	2.219	0.874	52°
1.	" " monochlorinated	$C_2H_4Cl_2$	3.478	1.174	147°
2.	" " bichlorinated.....	$C_2H_3Cl_3$	4.530	1.372	167°
3.	" " trichlorinated.....	$C_2H_2Cl_4$	5.799	1.530	216°
4.	" " quadrichlorinated....	C_2HCl_5	6.975	1.604	295°
5.	" " perchlorinated.....	C_2Cl_6	—	1.619	252°

The 1st, called chloride of aldehyde, is employed for preparing the others. *Prep.* It is formed by exposing a mixture of chlorine and chlorohydric ether to the rays of the sun, when a violent action takes place, with the disengagement of chlorohydric acid, and the formation of chloride of aldehyde. The ether should be in excess. The product is washed with water, rectified in a water-bath, and distilled with caustic lime, to free it from muriatic acid. The 1st few drops and the last 4th are removed, the latter containing a compound more charged with chlorine.

Prop. Pure chloride of aldehyde is a colorless, very mobile liquid, resembling closely in odor the chloride of éläyle (chlorohydrate of chloride of acetule—*Liebig*), (oil of olefiant gas), with a sweet, peppery taste; spec. grav. 1.174 at 62.6°; boils at 147.2°; density of vapor by exper. 3478. It is isomeric with oil of olefiant gas, differing from it in its boiling point, and in its behavior to potassium and an alcoholic solution of potassa, with each of which it may be distilled without decomposition. The 2d is formed by saturating with chlorine a considerable quantity of the preceding chloraldehyde, under a stratum of water in a cylinder, the latter being connected with a cooled recipient to collect one of the

volatile products. After the action has continued about 2 days, the liquid is distilled—the 1st and last 4ths being separated from the middle half. This last is the bichlorinated chlorohydric ether, or chloride of acetule = $C_4H_3Cl_3$. It is slowly decomposed by an alcoholic solution of potassa into chloride of potassium and acetic acid. The 1st and last 4ths of the distilled liquid serve for the production of the 3d and 4th compounds; the chief hinderance to obtaining which pure, lies in the difficulty of separating them by distillation; and hence the substance should be analyzed from time to time to ascertain when the due proportion of chlorine is present. The 5th and last is generated by the farther action of chlorine on the volatile product above mentioned. It is also produced by the exposure of an excess of chlorine and chloride of ethule to the rays of the sun. It is the sesquichloride of carbon.

Under *Acetic Acid* it was shown that that acid is formed by the oxidation of alcohol, 2 equiv. of hydrogen being removed, and replaced by 2 equiv. oxygen. Chlorine has a similar reaction, producing the oxychloride of acetule (chloride of ether).

Oxybichloride of Acetule. Syn. Ger. Chloräther II., or Acetyloxydchlorid (*Liebig*). Fr. Ether chloruré (*Malaguti*).

Formula, $C_4H_3Cl_2O$, or $C_4H_3Cl_2 \left\{ \begin{smallmatrix} O \\ \vdots \end{smallmatrix} \right\}$ or $Ac Cl_2 \left\{ \begin{smallmatrix} O \\ \vdots \end{smallmatrix} \right\}$				
Composition.	Form.	H = 1	O = 100	In 100.
4 eq. carbon.....	C_4	24	300.48	22.88
3 " hydrogen.....	H_3	3	37.50	2.82
1 " oxygen.....	O	8	100.00	7.54
2 " chlorine.....	Cl_2	71	887.50	66.76
1 " oxychloride of acetule.....		106	1325.48	100.00

(*Malaguti*.)

Prep. Washed and dry chlorine is passed through anhydrous ether, being wholly absorbed at first, the liquid becoming yellow, and increasing in bulk. After several hours the absorption diminishes, while muriatic acid gas is gradually disengaged, and at length increases to such violence that the liquid should then be cooled to below 32°; chlorohydric ether is evolved at the same time. When the disengagement of these two gaseous bodies ceases, the continued action of chlorine is assisted by a temperature of 194°, until the boiling point of the liquid begins to pass 212°. *Malaguti* passed chlorine for 40 hours through 100 grammes of ether. The product, a yellow, acid, fuming liquid is distilled in a water bath, the temperature being raised carefully and gradually until it begins to exhibit a darker color, which is generally 275° to 287.6°; then washed with water till perfectly neutral to litmus, and dried in vacuo over caustic lime and sulphuric acid.

Prop. A colorless, transparent, oily liquid, of an agreeable taste and odor, like oil of fennel-seed; spec. grav. 1.5008; boils, and is decomposed at 284°; decomposed gradually by contact with water into products soluble in water (chlorohydric and acetic acids?) An alcoholic solution of potassa instantly decomposes it into acetate of potassa and chloride of potassium, thus, $C_4H_3O Cl_2 + 3 KO = KO, C_4H_3O_3 + 2 K Cl$. Farther decomposed by

dry ammonia; when in solution in dry alcohol it is not changed by ammonia. In hydrous alcohol with ammonia, or with the latter, when moist, it is converted into muriate and acetate of ammonia. Sulphuric acid blackens it, forming muriatic acid and charcoal.

Oxymonochloride of Acetule (*Éther souschloruré*, *Malaguti*). Potassium, when heated with the preceding, abstracts 1 equiv. chlorine, forming a gaseous body and chloride of potassium; thus, $C_4H_3O Cl_2 + K = K Cl + C_4H_3O Cl$. The latter is the new substance.

Oxybisulphuret of Acetule. Compounds of an analogous nature, in which the chlorine is wholly or partially replaced by sulphur, may be obtained by the action of sulphuretted hydrogen gas on the oxychloride. When that gas is passed through the liquid, hydrochloric acid is disengaged, and there is formed an oily, colorless, fetid liquor, which blackens on exposure to the air, and gradually passes for the most part into a crystalline mass. Hot alcohol dissolves this; and on cooling deposits tolerably large colorless prisms, fusible between 228° and 235°; not volatile, insoluble in water, soluble in alcohol and ether. The formula of this compound, which may be called

oxysulphuret of acetule, is $C_4H_3O \left\{ \begin{smallmatrix} O \\ \vdots \end{smallmatrix} S_2 \right\}$, according to which it is anhydrous acetic acid in

which 2 equiv. oxygen have been replaced by 2 equiv. sulphur. In contact with an alcoholic solution of potash, it forms sulphuret of potassium and acetate of potassa. The mother-liquid of these crystals, on further evaporation, yields yellow unctuous scales, fusible at about 160°, and possessing analogous properties. It is distinguished from the 1st by containing only 1 eq. sulphur and, in the place of the second, 1 eq.

chlorine. Its formula is $\text{C}_4\text{H}_3\text{Cl} \begin{Bmatrix} \text{O} \\ \text{S} \end{Bmatrix}$ (*Oxychlorosulphuret of Acetule*). With an alcoholic solution of potassa, this body gives sulphuret and chloride of potassium, with acetate of potassa.

The compounds of oxide of ethule (ether) with acids are acted on by chlorine very much as the ether itself; with this difference, that the acids, when not altered by chlorine, and, when they are altered by it, the new substances formed remain in combination with the oxychloride of acetule.

Malaguti examined the action of chlorine on the neutral compounds of acids with the oxide of ethule (ethers), and called the neutral oily compounds of these ethers chloracetic, chloroxalic, chlorobenzoic, chloroformic ethers; but by decomposition with potassa they produce no alcohol, but always acetic acid, which, together with the original acid of the ether, combines with the potassa. The constant appearance of acetic acid, by their decomposition, shows

them evidently to be compounds of acetule. Thus acetic ether gives with chlorine a body (*CHLORACETIC ETHER*, which see) consisting of $\text{C}_8\text{H}_6\text{O}_4\text{Cl}_2$, which may be represented by the formula $\text{C}_4\text{H}_3\text{O}_3 + \text{C}_4\text{H}_3\text{Cl}_2 \begin{Bmatrix} \text{O} \\ \text{O} \end{Bmatrix}$, or 1 equiv. acetic acid, and 1 equiv. oxychloride of acetule. In some ethers the acid, as well as oxide of ethule, are attacked by chlorine: thus, benzoic ether takes up 3 equiv. chlorine, but gives off only 2 equiv. chlorohydric acid, so that the substance formed consists of $\text{C}_{18}\text{H}_8\text{O}_3\text{Cl}_3$, or of chloride of Benzule ($\text{Bz. Cl} = \text{C}_{14}\text{H}_5\text{O}_2, \text{Cl}$) + $\text{C}_4\text{H}_3\text{Cl}_2 \begin{Bmatrix} \text{O} \\ \text{O} \end{Bmatrix}$ (oxychloride of acetule). These

compounds will be found under their several titles, *CHLORACETIC, CHLOROBENZOIC, &c.*, ethers.

The preceding decompositions refer to the removal of so much of the hydrogen of ether ($\text{C}_4\text{H}_5\text{O}$) as to leave acetule (C_4H_3), and to the replacement of oxygen either wholly or in part. But the hydrogen may be still farther or wholly removed, forming an aldehyde. Thus, *CHLORAL* (which see) is composed of $\text{C}_4\text{H Cl}_3\text{O}_2$, or perhaps more properly $\text{C}_4\text{Cl}_3\text{O} + \text{HO}$ (compare this with aldehyde in the former part of the article *ACETULE*), and *CHLORACETIC ACID* (see this), which is composed of $\text{C}_4\text{Cl}_3\text{O}_3 + \text{HO}$ (compare the formula of *Acetic Acid*).

The following table represents the various compounds of acetule which have been described or alluded to in the present article:

Tabular View of the Compounds of Acetule.

C_4H_3	Acetule	} hypothetical.
$\text{C}_4\text{H}_3\text{O}$	Oxide of acetule	
$\text{C}_4\text{H}_3\text{O} + \text{HO}$	Hydrated oxide of acetule (aldehyde).	
$\text{C}_4\text{H}_3\text{O}_2 + \text{HO}$	Acetulous acid (aldehydic acid).	
$\text{C}_4\text{H}_3\text{O}_3 + \text{HO}$	Acetic acid.	
$\text{C}_4\text{H}_3\text{O} + \text{HCl}$	Chlorohydrate of oxide of acetule (hypothetical)	
$\text{C}_4\text{H}_3\text{Cl} \begin{Bmatrix} \text{O} \\ \text{O} \end{Bmatrix}$	Oxymonochloride of acetule.	
$\text{C}_4\text{H}_3\text{Cl}_2 \begin{Bmatrix} \text{O} \\ \text{O} \end{Bmatrix}$	Oxybichloride of acetule.	
$\text{C}_4\text{H}_3\text{S}_2 \begin{Bmatrix} \text{O} \\ \text{O} \end{Bmatrix}$	Oxybisulphuret of acetule.	
$\text{C}_4\text{H}_3\text{S} \begin{Bmatrix} \text{O} \\ \text{Cl} \end{Bmatrix}$	Oxychlorosulphuret of acetule.	
$\text{C}_4\text{H}_3\text{Cl} + \text{HCl}$ ($\text{C}_4\text{H}_4\text{Cl}_2$)	Monochlorinated chlorohydric ether (<i>Chloraldehyde. Regnault</i>).	
$3(\text{C}_4\text{H}_4\text{O}_2) + 2\text{CyCl} + 2\text{HO}$	Chlorocyan-aldehyde.	
$\text{C}_4\text{H}_3\text{Cl}_3$	Terchloride of acetule (bichlorinated chlorhydric ether, <i>Regnault</i>).	
$\text{C}_4\text{Cl}_3\text{O} + \text{HO}$	Chloral.	
$\text{C}_4\text{Br}_3\text{O} + \text{HO}$	Bromal.	
$\text{C}_4\text{Cl}_3\text{O}_3 + \text{HO}$	Chloracetic acid.	

Admitting Elayl (olefiant gas= C_4H_4) to be a hyduret of acetule ($\text{C}_4\text{H}_3 + \text{H}$), as assumed by Liebig, the series of acetule formed from it would be:

C_4H_3	Acetule.
$\text{C}_4\text{H}_3 + \text{H}$	Hyduret of acetule (olefiant gas).
$\text{C}_4\text{H}_3\text{Cl}$	Protochloride of acetule.
$\text{C}_4\text{H}_3\text{Cl} + \text{HCl}$	Hydrochlorate of chlor. of acetule (oil of olefiant gas)
$\text{C}_4\text{H}_3\text{Br}$	Protobromide of acetule.
$\text{C}_4\text{H}_3\text{Br} + \text{HBr}$	Hydrobromate of bromide of acetule.
$\text{C}_4\text{H}_3\text{Cl}_3$ (?).....	Terchloride of acetule.
$\text{C}_4\text{H}_3\text{H} + 4\text{SO}_3$ ($\text{C}_4\text{H}_3\text{S}_2\text{O}_5 + \text{HO}, 2\text{SO}_3$?)	Hyposulphoacetylic acid.
$\text{C}_4\text{H}_3\text{Cl} + \text{Pt}_2\text{Cl}$	Chloride of platinum and acetule.
$\text{C}_4\text{H}_3\text{Cl} + \text{Pt}_2\text{Cl} + \text{KCl}$	Chloride of potassium, platinum, and acetule.
$\text{C}_4\text{H}_3\text{Cl} + \text{Pt}_2\text{Cl} + \text{NH}_3$	Chloride of platinum and acetule, with ammonia.

For the various views on this subject see Berz. *Jahresbericht*, 1841; *Lehrb.* vol. viii.; Liebig's *Turner*, p. 895, &c.; *Handwörterb. d. Chemie*, ii. 174, &c.; Malaguti in Lieb. and Wöhler's *Annalen*, xxxii.; Regnault, in the same, xxxiii., &c.

ACETULOUS ACID. See *Aldehydic acid*, under **ACETULE**.

ACHIRITE. *Min.* See **SILICEOUS MALACHITE**.

ACHROMATIC. *Optics.* Free from color. Achromatic glasses are lenses or combinations of them, designed to refract light without producing color in the image.

ACICULAR BISMUTH GLANCE. *Min.* See **NEEDLE-GRE**.

ACIDIFIABLE. *Chem.* Capable of being converted into an acid, such as sulphur, carbon, &c., which by oxygen may be converted into sulphurous, carbonic acids, &c.

ACIDIMETRY. *Chem. Tech.* The determination of the strength of acids without resorting to direct analysis, the methods being always more or less physical, such as specific gravity, boiling point, behavior to light, and electricity. The most convenient for liquids is the spec. grav., but it cannot always be employed, since the same acid of different strengths may have the same density (see **ACETIC ACID**); and since foreign ingredients may affect the density and not the acidity. The best method is unquestionably to neutralize measured quantities of the dilute acid with measured quantities of a liquid containing a given quantity of alkali, such as caustic ammonia, a solution of carbonate, or bicarbonate of potassa, &c. Of all alkaline bodies caustic ammonia seems to be generally the most convenient, being a strong base always in a convenient form for use, and its salts soluble. If a certain standard of ammonia could be adopted, tables might be constructed for exhibiting, by its use, the quantity of dry acid in any solution.

ACIDS. *Chem.* A large class of bodies in the organic and mineral kingdoms, found sometimes free, but usually combined. In the earlier days of the modern science of chemistry it was usual to apply this term to such oxidized bodies as possessed a sour taste, reddened certain vegetable blue colors, and neutralized alkalies. It soon became evident that the definition of the term acid must be extended; for, 1st, the hydracids, such as the muriatic, contain no oxygen, excepting when in an aqueous solution; 2d, some bodies, analogous to acids, and presenting all other characters of acids, are insoluble in water, and therefore can neither redden blues nor taste sour, such as the silicic acid (flint), which closely resembles the boracic; and lastly, some acids cannot conceal or neutralize the alkaline nature of potassa or soda, excepting when in excess: thus the carbonates of potassa and soda and the sulphite of soda exhibit alkaline reaction. The subsequent development of sulphur salts by Berzelius led to the farther extension of the term acid to certain sulphurets, such as sulphuretted hydrogen, sulphuret of arsenic, &c. Again, some chemists regard certain metallic chlorides as acids, such as the chloride of platinum. It is therefore difficult, if not impossible, to give a

definition of acids which may at the same time be precise and chemically correct. We may with sufficient accuracy regard as acids those bodies which unite with the oxide, sulphuret, or chloride of potassium, and produce compounds analogous to the salts which sulphuric acid, sesquisulphuret of arsenic, or chloride of platinum form, severally, with the above compounds of potassium. Or we may say more concisely and perhaps more correctly that an acid is the electronegative compound of a salt consisting of more than two elements.

The extensive researches of the last few years, both in organic and inorganic chemistry, have led to novel views of the constitution of acids and salts; and although I shall not adopt these views in treating practically of the various salts or acids, a knowledge of them is essential to a proper understanding of the present transient state of chemical science. The following extract from Liebig's *Turner* presents a sufficiently clear and extended view of the subject. The modern views relative to salts and organic acids will be found under **COMPOUND RADICALS**, **ORGANIC ACIDS**, and **SALTS**.

"In regard to acids, the first point to be noticed is, that all so-called oxygen acids, in the free, or what may be called the *active* state, contain hydrogen. On referring to the descriptions of the mineral acids, it will be found, for example, that they are described as combining with water when separated from their combinations. Oil of vitriol is $\text{SO}_3\cdot\text{HO}$; nitric acid $\text{NO}_3\cdot\text{HO}$, &c. The latter, indeed, cannot exist in the supposed anhydrous state, NO_3 ; and this is the case with a large majority of all known acids. Sulphuric acid and phosphoric acid, no doubt, may be obtained anhydrous, SO_3 and P_2O_5 ; but it is worthy of especial notice, that in this state they do not possess the properties of these acids, and only acquire them on the addition of water. The compound of dry sulphuric acid and ammonia, $\text{SO}_3\cdot\text{NH}_3$, is not sulphate of ammonia, but a distinct compound. Moreover, these anhydrous acids combine with water with the greatest vehemence, and then assume their active characters. The principal exceptions are carbonic acid and chromic acid; but, on the other hand, none of the organic acids can exist without water, that is, without hydrogen.

It is obvious that hydrogen is essential to the hydracids. Now the view which I wish here to explain considers both these classes of acids as hydracids, and thus unites in one class or series bodies having the most perfect analogy in properties. According to this view, therefore, the general formula of a hydracid is $\text{X} + \text{H}$: X being an acid-radical which may be either simple or compound. Thus in hydrochloric, hydriodic, and hydrosulphuric acids respectively, X is represented by Cl , I , or S . In hydrocyanic and hydrosulphocyanic acids, X is represented by $\text{Cy}=\text{C}_2\text{N}$, and by $\text{CyS}_2=\text{C}_2\text{NS}_2$, respectively.

In the hydrated oxygen acids, to which alone, and not to the anhydrous acids, this theory applies, X is always a compound, and always contains oxygen. Thus in hydrated sulphuric acid, commonly so called, and represented by $\text{SO}_3\cdot\text{HO}$, X is represented by SO_4 ; in nitric

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acid, NO_3HO , $\text{X}=\text{NO}_2$; and in metaphosphoric acid, $\text{P}_2\text{O}_5\text{HO}$, $\text{X}=\text{P}_2\text{O}_6$; and the true formulæ of these acids are $\text{SO}_6\text{H}_2\text{NO}_6\text{H}$ and $\text{P}_2\text{O}_6\text{H}_2$, respectively.

Further, among the organic acids we find a corresponding constitution. In acetic acid (hydrated) $\text{C}_4\text{H}_3\text{O}_3\text{HO}$, $\text{X}=\text{C}_2\text{H}_3\text{O}_4$; in hydrated formic acid, $\text{C}_2\text{HO}_3\text{HO}$, $\text{X}=\text{C}_2\text{HO}_4$, &c.

The next point to be noticed is, that acids exist, the general formula of which is $\text{X}+\text{H}_n$; that is, in which X combines with two or more equivalents of H , and which are called polybasic acids. Those acids, above described, in which there is 1 eq. of H , are called monobasic

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acids. Where 2 eq. of H are present, the acid is bibasic; with 3 eq. of H , tribasic, and so on. The reason of this nomenclature will be more clearly seen under **SALTS**.

Examples of this kind are, pyrophosphoric acid, $\text{P}_2\text{O}_5\text{, }2\text{HO}$, which is bibasic, its true formula being $\text{P}_2\text{O}_7\text{H}_2$; phosphoric acid, $\text{P}_2\text{O}_5\text{, }3\text{HO}$, which is a tribasic acid, $\text{P}_2\text{O}_8\text{H}_3$; and arsenic acid, $\text{As}_2\text{O}_5\text{, }3\text{HO}$; also a tribasic acid, $\text{As}_2\text{O}_8\text{H}_3$.

But it is among the organic acids that we find the most numerous and striking examples of polybasic acids. The following table contains the formulæ of some of these.

Meconic acid.....	$\text{C}_{14}\text{H O}_{11}$	+ 3HO (tribasic)	$=\text{C}_{14}\text{H O}_{14} + \text{H}_3$.
Cyanuric acid	$\text{Cy}_3 \text{O}_3$	+ 3HO (tribasic)	$=\text{Cy}_3 \text{O}_6 + \text{H}_3$.
Citric acid	$\text{C}_{12}\text{H}_5\text{O}_{11}$	+ 3HO (tribasic)	$=\text{C}_{12}\text{H}_5\text{O}_{14} + \text{H}_3$.
Tannic acid.....	$\text{C}_{18}\text{H}_5\text{O}_9$	+ 3HO (tribasic)	$=\text{C}_{18}\text{H}_5\text{O}_{12} + \text{H}_3$.
Tartaric acid.....	$\text{C}_8 \text{H}_4\text{O}_{10}$	+ 2HO (bibasic)	$=\text{C}_8 \text{H}_4\text{O}_{12} + \text{H}_2$.
Komenic acid.....	$\text{C}_{12}\text{H}_2\text{O}_8$	+ 2HO (bibasic)	$=\text{C}_{12}\text{H}_2\text{O}_{10} + \text{H}_2$.
Fulminic acid.....	$\text{Cy}_2 \text{O}_2$	+ 2HO (bibasic)	$=\text{Cy}_2 \text{O}_4 + \text{H}_2$.
Mucic acid.....	$\text{C}_{12}\text{H}_8\text{O}_{14}$	+ 2HO (bibasic)	$=\text{C}_{12}\text{H}_8\text{O}_{16} + \text{H}_2$.

Moreover, there are also polybasic acids which contain no oxygen, analogous in this respect to hydrochloric and hydrocyanic acids. Thus ferrocyanic acid is represented by $\text{Cy}_3\text{Fe} + \text{H}_2$; and ferridcyanic acid is $\text{Cy}_3\text{Fe}_3 + \text{H}_3$.

It will be obvious at a glance, that this theory of acids possesses the advantages of simplicity and of uniting in classification a vast number of bodies, similar in properties, which have formerly been arbitrarily separated. But the chief advantage attending it is, that it ena-

bles us to effect the same union into one class of all the salts of the acids containing hydrogen. It is in examining the salts, moreover, that we find the strongest arguments in favor of the theory as applied to acids." (See **SALTS**.)

If these views (embraced under the *Binary theory of salts*) be admitted, we shall be obliged to acknowledge the existence of a large number of radicals; thus, for example, we shall have three radicals where we now admit one in phosphoric acid:

Older View.

Monobasic acid.....	$\text{PO}_5 + \text{HO}$
Bibasic	$\text{PO}_5 + 2\text{HO}$
Tribasic	$\text{PO}_5 + 3\text{HO}$

New Theory,

$\text{PO}_6 + \text{H}$	(Metaphosphoric acid).
$\text{PO}_7 + \text{H}_2$	(Pyrophosphoric acid).
$\text{PO}_8 + \text{H}_3$	(Phosphoric acid).

Should these views be followed, a radical change of nomenclature must necessarily ensue, and Graham proposes to call the radical of sulphuric acid, $=\text{SO}_4$, sulphatoxygen, and the sulphates sulphatoxides, those of nitrogen, $=\text{NO}_6$, nitratoxides, &c. Daniell, following Faraday's electrical nomenclature of *ions*, calls them severally oxy-sulphion, oxy-nitron, &c.

The following tabular view presents all the acids described in the present work, and indeed all known acids, with the exception of a few which are derived by substitution from those described, such as the chloro-sulphuric, $=\text{SO}_2\text{Cl}$, in which an equivalent of chlorine replaces one of oxygen in the sulphuric SO_3 , or a few which are obtained by decomposing

an organic acid by sulphuric, nitric, &c.; such as nitromeconic, hyposulpho-benzoic acids, &c. These will be subsequently described under those from which they are derived. They are generally presented in the hydrated state, where it is not otherwise specified, excepting in the case of a few organic acids whose content of water has not been determined. Although there are acknowledged difficulties in the present changing state of chemical science in arranging the acids in a correct scientific order, yet I have attempted it on the principles of similarity of properties, or connection between the principal and its derivatives. Many organic acids are not included in the list, because they have either not been sufficiently investigated or their existence is doubtful.

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I. TABLE OF INORGANIC ACIDS.

A. OXYACIDS.			
Sulphur Group.	<i>Sulphur.</i>		
	Hyposulphurous.....	SO or S ₂ O ₂	
	Bisulpho-hyposulphuric.....	S ₄ O ₅	
	Sulpho-hyposulphuric.....	S ₃ O ₅	
	Sulphurous.....	SO ₂	
	Hyposulphuric.....	S ₂ O ₅	
	Sulphuric.....	SO ₃	
	<i>Selenium.</i>		
	Selenious.....	SeO ₂	
	Selenic.....	SeO ₃	
Phosphorus Group.	<i>Tellurium.</i>		
	Tellurous.....	TeO ₂	
	Telluric.....	TeO ₃	
	<i>Nitrogen.</i>		
	Nitrous.....	NO ₃	
	Hyponitric.....	NO ₄	
	Nitric.....	NO ₅	
	<i>Phosphorus.</i>		
	Hypophosphorous.....	PO	
	Phosphorous.....	PO ₃	
Car. G.	Phosphoric.....	PO ₅	
	<i>Arsenic.</i>		
	Arsenious.....	AsO ₃	
	Arsenic.....	AsO ₅	
	<i>Antimony.</i>		
	Antimonious.....	SbO ₄	
	Antimonic.....	SbO ₅	
	<i>Carbonic.</i>	CO ₂	
	Boracic.....	BO ₃	
	Silicic.....	SiO ₃	
		<i>Chlorine.</i>	
Halogen Group.	Hypochlorous.....	ClO	
	Chlorous.....	ClO ₃	
	Hypochloric.....	ClO ₄	
	Chloric.....	ClO ₅	
	Perchloric.....	ClO ₇	
		<i>Iodine.</i>	
Halogen Group.	Iodous (?)		
	Iodic.....	IO ₅	
	Periodic.....	IO ₇	
		<i>Bromine.</i>	
Halogen Group.	Hypobromous (?)		
	Bromic.....	BrO ₅	
Chrom. Gr.	Manganic.....	MnO ₃	
	Hypermanganic.....	Mn ₂ O ₇	
	Ferric (Iron).....	FeO ₃ (?)	
	Chromic.....	CrO ₃	
	Vanadic.....	VO ₃	
Titan. G.	Tungstic.....	WO ₃	
	Molybdic.....	MoO ₃	
	Columbic.....	TaO ₃	
	Titanic.....	TiO ₂	
	Stannic (Tin).....	SnO ₂	
		<i>B. HYDRACIDS.</i>	
Halogen G.	Iodohydric.....	HI	
	Bromohydric.....	HBr	
	Chlorohydric.....	HCl	
	Fluohydric.....	HF	
Sul. G.	Sulphohydric.....	HS	
	Selenohydric.....	HSe	
	Tellurohydric.....	HTe	

II. TABLE OF ORGANIC ACIDS.

Name.	Whence obtained.	Formula.	Authority.
<i>Carbonic Oxide Series.</i>			
Oxalic.....	Leaves of rumex, oxalis, &c.	Cryst. C ₂ O ₃ +3 HO	Dulong & Berzelius
Rhodizonic...	In preparing potassium	In salts C ₇ O ₇ +3 MO	Gmelin
Croconic.....	Ditto	Hypoth. dry C ₅ O ₄	Gmelin
Mellitic.....	In honey-stone	Cryst. C ₁₂ O ₃ +HO	Klaproth, Wöhler
Euchronic...	From mellit. of ammonia	Dried at 392° C ₁₂ NO ₆ +2HO	Wöhler
<i>Acids in Fruits, &c.</i>			
Tartaric.....	Juice of the grape, &c.	Cryst. C ₈ H ₄ O ₁₀ +2 HO	Scheele, &c.
Tartralic.....	Tartaric by fusion	2 (C ₈ H ₄ O ₁₀)+3 HO	Fremy
Tartrellic.....	Ditto	C ₈ H ₄ O ₁₀ +HO	Do.
Tartaric (?)..	Tartaric	C ₈ H ₄ O ₁₀	Do.
Pyrotartaric..	Tartaric by heat	Liquid C ₆ H ₃ O ₅ +HO	Berzelius
Pyrotartaric..	Ditto	Solid C ₅ H ₃ O ₃ +HO	Pelouze
Racemic.....	Juice of the grape, &c.	Dried at 212° C ₄ H ₂ O ₅ +HO	Berz. Fremy
Citric.....	Fruit of aurantiacæ	At 212° C ₁₂ H ₅ O ₁₁ +3 HO	Scheele, Berz.
Aconitic.....	Aconite, and citric ac. by heat	C ₄ HO ₃ +HO	Peschier, Crasso
Itaconic.....	From aconitic by heat	C ₅ H ₂ O ₃ +HO	Crasso, Baup
Citraconic...	From itaconic by heat	2 (?) (C ₅ H ₂ O ₃ +HO)	Do.
Malic.....	Apples and many fruits	C ₈ H ₂ O ₈ +2 HO	Liebig, &c.
Fumaric.....	From malic by slow heat	C ₄ HO ₃ +HO	Lassaigne, Pelouze
Maleic.....	From malic by quick heat	C ₈ H ₂ O ₆ +2 HO	Pelouze, Liebig
<i>Tannin Series.</i>			
Tannic.....	Astring. barks, nut-galls, &c.	C ₁₈ H ₅ O ₉ +3 HO	Berz., &c.
Gallic.....	Nut-galls, tannic acid, &c.	Cryst. C ₇ HO ₃ +3 HO	Scheele, &c.
Pyrogallic...	From gallic by heat	C ₆ H ₃ O ₃ (?) C ₈ H ₄ O ₄	

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Name.	Whence obtained.	Formula.	Authority.
<i>Tannin Series, cont.</i>			
Metagallic....	From gallic by heat	$C_6H_2O_2$ (?) $C_{12}H_3O_3 + HO$	Pelouze
Ellagic.....	Fermenta. of gallic	$C_7H_2O_4 + HO$	Chevr. Pelouze
Japonic.....	} From catechu	Not fully determined	Svanberg
Rubinic.....			
Catechutannic	From catechu in ether	(?) $C_{18}H_8O_8 + HO$	Woskresensky
Kinic.....	Bark of cinchonaceæ	$C_7H_4O_4 + 2 HO$	
Meconic.....	Juice of papaveraceæ	At 212° $C_{14}H_{11}O_{11} + 3 HO$	Robiquet
Komenic.....	Decomp. of meconic	Cryst. $C_{12}H_2O_8 + 2 HO$	Do.
Pyromecanic..	From komenic by heat	Cryst. $C_{10}H_3O_5 + HO$	Sertuerner, Robiq.
<i>Benzoic Series.</i>			
Benzoic.....	Resins of the styracæ	Cryst. $C_{14}H_5O_3 + HO$	Wöhl. & Liebig
Benzilic.....	From benzoine by potassa	Cryst. $C_{28}H_{11}O_5 + HO$	Liebig
Formobenzoic	Oil of bitter almonds	$C_{16}H_7O_5 + HO$	Winkler, &c.
Amygdalinic..	Amygdaline in bit. almonds	$C_{40}H_{26}O_{12} + HO$	Wöhl. & Liebig
<i>Series of Salicine, Indigo, and Aloes.</i>			
Saliculous....	Volat. oil of spiræa ulmaria	$C_{14}H_5O_3 + HO$	Pagenstecher, &c.
Saliculic.....	Heating saliculous & potassa	$C_{14}H_5O_5 + HO$	Piria
Melanic.....	From saliculite of potassa	$C_{10}H_4O_5$	Piria
Isatic.....	Indigo by oxidation	Dry $C_{16}H_6NO_5$	Erdman, Laurent
Sulphoindigotic.....	and hyposulpho-indigotic	Not sufficiently examined	
Anilic (Indigotic).....	Dilute nitric acid with indigo	$C_{14}H_4NO_9 + HO$	Dumas, &c.
Picric (Carbazotic).....	Strong nitric acid and indigo	$C_{12}H_2N_3O_{13} + HO$	Dum. Marchand
Chrysanic.....	Indigo with alkali	Not determined	Fritzsche
Anthranilic..	Ditto and manganese	$C_{14}H_6NO_3 + HO$	Do.
Polychromic..	From aloes with nitric acid	Not determined	Braconnot
Chrysammic..	Ditto	$C_{15}HN_2O_{12} + HO$	Schunck
Chrysolepic..	Ditto	$C_{12}H_2N_3O_{13} + HO$	Do.
<i>Acids from Essential Oils and Resins.</i>			
Cinnamic.....	Cinnamon	Cryst. $C_{18}H_7O_3 + HO$	Dumas, Peligot
Caryophyllic..	Caryophyllus (cloves)	$C_{20}H_{11}O_3 + HO$	Böckman, Eitling
Cuminic.....	Cuminum (cumin)	$C_{20}H_{11}O_5 + HO$	Gerhardt & Cahours
Camphoric...	Camphor and nitric acid	Hydr. $C_{10}H_7O_3 + HO$	Malaguti, Walter
Campholic...	Camphor and potassa	$C_2OH_{17}O_3 + HO$	Delalande
Sylvic.....	Common resin	$C_{20}H_{16}O_2$	Unverdorben, Rose
Pinic.....	Ditto	$C_{20}H_{15}O_2$	Do. Liebig
Colopholic...	Distillation of pinic acid	Not determined	
Pimaric.....	In pinus maritima	Similar to preceding acids	Laurent
Pyromaric...	Distillat. of pimaric	Ditto	Do.
Azomaric.....	Pimaric and nitric acid	$C_{20}H_{11}NO_8$	Do.
Turpentinic..	Oil of turpentine	$C_{14}H_9O_7$	Bromeis
<i>Series of Oily Acids.</i>			
Butyric.....	From butter	$C_8H_6O_3 + HO$	Bromeis
Caproic.....	Ditto	Hydr. $C_{12}H_9O_3 + HO$	Chevreul
Capric.....	Ditto	Dry $C_{18}H_{14}O_3$	Do.
Hircic.....	Fat of the goat	Not determined	Do.
Phocenic.....	Berries of viburnum opulus	$C_{10}H_7O_3 + HO$	Do.
Sabadillic....	Seeds of veratrum sabadilla	Not determined	Pelletier & Caventou
Veratric.....	Ditto	$C_{18}H_9O_7 + HO$	Schrötter
Crotonic.....	Seeds of croton tiglium	Not determined	Pelletier & Caventou
Valerianic....	Valeriana officinalis	Hydr. $C_{10}H_9O_3 + HO$	Eitling, Dumas
Rocellic.....	Rocella tinctoria	Cryst. $C_{17}H_{16}O_4$	Liebig
Cocoic.....	Butter of the cocoa-nut	Hydr. $C_{27}H_{26}O_3 + HO$	Bromeis
Myristic (Sericic).....	Butter of nutmegs	Cryst. $C_{28}H_{27}O_3 + HO$	Playfair
Palmitic.....	Palm-oil	Hydr. $C_{32}H_{31}O_3 + HO$	Fremy, Stenhouse
Margaric.....	Oils and fats	$C_{34}H_{33}O_3 + HO$	Varrentrapp, &c.
Stearic.....	Ditto	$C_{36}H_{35}O_5 + 2 HO$	Chev., Redtenbacher
Oleic.....	Ditto	(?) Hydr. $C_{44}H_{39}O_4 + HO$	Varrentrapp
Butyroleic....	Butter	$C_{34}H_{30}O_4 + HO$	Bromeis
Suberic.....	Nitric and the oily acids, cork.	Cryst. $C_8H_6O_3 + HO$	Bromeis, &c.

ACIDS.

ACIDS.

Name.	Whence obtained.	Formula.	Authority.
<i>Series of Oily Acids, cont.</i>			
Succinic.....	Nitric & the oily acids, amber	Hydr. $C_4H_2O_3 + HO$	Bromeis, &c.
Sebacic.....	Distill. of oils and fats	Hydr. $C_{10}H_8O_3 + HO$	Dum., Redtenbacher
Elaidic.....	Nitrous acid and oleine	Hydr. $C_{72}H_{66}O_6 + 2 HO$	Meyer, &c.
Palmic.....	Do. and palmitine	Not determined	
Pimelic.....	Formed with suberic	$C_6H_5O_3 + HO$	Laurent, Bromeis
Adipic.....	Ditto	$C_{11}H_9O_7 + 2 HO$	Bromeis
Lipic.....	Ditto	$C_5H_3O_4 + HO$	Laurent
Azoleic.....	Ditto	Hydr. $C_{14}H_{13}O_3 + HO$	Bromeis
Metamargaric..	Sulphuric with margaric	(?) Dry $C_{72}H_{74}O_6$	Fremy
Hydromargari- tic.....	Ditto	(?) Dry $C_{74}H_{74}O_{10}$	Do.
Hydromargric..	Ditto	(?) Dry $C_{70}H_{71}O_{10}$	Do.
Metoleic.....	Sulphuric with oleic	(?) $C_{70}H_{83}O_8 + HO$	Do.
Hydroleic.....	Ditto	(?) $C_{70}H_{64}O_9$	Do.
<i>Ethulic Series.</i>			
Saccharic.....	Nitric acid and sugar	$C_{12}H_5O_{11} + 5 HO$	Thaulow
Mucic.....	Ditto and sugar of milk	Hydr. $C_{12}H_8O_{14} + 2 HO$	Malaguti, Berzelius
Pyromucic.....	Distillat. of mucic	$C_{10}H_3O_5 + HO$	Malag. Boussing.
Sulphosaccha- ric.....	Sulphuric and grape-sugar	Not determined	Peligit
Sacchulmic....	Dilute sulphuric & cane-sugar	$C_{30}H_{15}O_{15}$	Malaguti
Glucic.....	Alkali and grape-sugar	(?) $C_{12}H_8O_8$	Peligit
Melassic.....	Ditto	$C_{24}H_{12}O_{10}$	Peligit & Dumas
Lactic.....	In ferment. anim. & veg. fluids	Hydr. $C_3H_5O_5 + HO$	
Sulphovinic...	Sulphuric and alcohol	$AeO, SO_3 + HO, SO_3$	
Phosphovinic..	Phosphoric and do.	$AeO + 2 HO + PO_5$	
Oxalovinic....	Oxal. ether & alcoholic potassa	$AeO, C_2O_3 + HO, C_2O_3$	
Xanthic.....	Bisulph. carbon, and do.	Hydr. $AeO + 2 CS_2 + HO$	
Cenanthic....	In fermented liquors	$C_{14}H_{13}O_2 + HO$	Pelouze, Liebig
Carbulsulphu- ric.....	Dry sulphuric and ether	$S_2C_4H_5O_{13}$	Magnus
Isethionic.....	Dry sulphuric and alcohol	$S_2O_5, C_4H_5O_2 + HO$	Magnus
Methionic....	Sulphuric and ether	Dry $S_2C_2H_3O_7$	
Althionic.....	Sulphuric and alcohol	Not determined	Regnault
Acetulous.....	Aq. aldehyde & oxide of silver	Hydr. $C_4H_3O_2 + HO$	Liebig
Acetic.....	Oxidation of alcohol	Cryst. $C_4H_3O_3 + HO$	Döbereiner
Chloracetic....	Cryst. acetic and chlorine	$C_4Cl_3O_3 + HO$	Dumas
Cacodulic....	Acetic and arsenious acids	$C_4H_6AsO_4 + HO$	Bunsen
Formic.....	High oxida. of veg. substances	Hydr. $C_2HO_3 + HO$	
<i>Acids of dry Distillation.</i>			
Sulphomethulic	Sulphuric and wood-alcohol	$C_2H_3O, HO + 2SO_3$	Dum. & Peligit, Kane
Hyposulpho- naphthalic...	Dry sulphuric on naphthaline	$C_{20}H_8S_2O_5, HO$	Faraday
Naphthalic....	Nitric & a chloro-naphthaline	$C_{16}H_4O_6 + 2 HO$	Laurent, Marignac
Sulphophenic..	Sulphuric and gas-naphtha	$C_{12}H_5O, 2 SO_3 + HO$	Laurent
Chlorophenic..	Chlorine and ditto	$C_{12}H_2Cl_3O + HO$	Do.
Chlorophenesic	Ditto	$C_{12}H_3Cl_2O + HO$	Do.
<i>Acids of Putrefaction.</i>			
Ulmic.....	Vegetable mould	$C_{40}H_{12}O_{12}$	Mulder
Geic.....	Ditto	$C_{40}H_{12}O_{12}$	Do.
Humous.....	Ditto	$C_{40}H_{14}O_{12}$	Do.
Humic.....	Ditto	$C_{40}H_{15}O_{15} + NH_3$	Do.
Crenic.....	Ditto	$C_{14}H_{16}NO_{12}$	Berzelius
Apocrenic....	Ditto	$C_{28}H_{14}N_6O_6$	Do.
Mudeseous....		$C_{12}H_5O_8 + 3 HO$	Johnston
Mudesic.....		(?) $C_{12}H_5O_{10} + HO$	Do.
Xylitic.....	Potassa with xylite	(?) $C_8H_6O_3$	Gmelin
<i>Cyanogen Series.</i>			
Cyanic.....	Decomp. of nitrog. compounds	Hydr. $C_2N(Cy), O + HO$	Wöhler
Fulminic.....	Nitric acid, silver, and alcohol	Salts $Cy_2O_2 + 2 MO$	Gay-Lussac & Liebig
Cyanuric.....	Decomp. of solid chlor. cyan.	Hydr. $Cy_3O_3 + 3 HO$	Wöhl. & Liebig
Cyanohydric (prussic)....	Amygdalæ and pomæ, &c.	CyH or C_2N, H	Scheele, Gay-Lussac

Name.	Whence obtained.	Formula.	Authority.
<i>Cyanogen Series, cont.</i>			
Sulpho-cyano-hydric.....	Seeds of cruciferae, &c.	CyS_2, H	Rink
Persulpho-cyano-hydric...	Decomp. of preceding	CyS_3, H	Wokresensky
Mellonhydric...	Acids & mellonide of potass.	C_6N_4, H	Liebig
Cyanilic.....	Mellone and dilute nitric	Not determined	Do.
<i>Acids from Animal Substances.</i>			
Choleic.....	Ox-gall	$C_{76}H_{66}N_2O_{22} (C_{42}H_{36}NO_{12})$	Demarçay
Choloidic.....	Chlorohydric acid and ox gall	$C_{72}H_{56}O_{12} (C_{38}H_{30}O_7)$	Liebig, Demar.
Fellanic and Fellic.....	Gall	Not determined	Berzelius, &c.
Cholanic and Cholinic. ...			
Cholic.....	Gall	$C_{74}H_{60}O_{18}$	Liebig, Gmelin
Lithofellic.....	Bezoar, biliary calculus	$C_{40}H_{35}O_7 + HO$	Wöhler
Cerebric.....	From the brain	Not determined	Vauquelin, Fremy
Cholesteric.....	Ditto, and bil. calcul.	$C_{11}H_9NO_5$	Pelletier & Caventou
Cetulic.....	Spermaceti	$C_{32}H_{31}O_3 + HO$	Dumas & Stass
Ceraic.....	Nitric acid and wax	(?) $C_{20}H_{20}O_3$	Hess
Hippuric.....	Urine of the horse	$C_{18}H_5NO_5 + HO$	Liebig
Uric.....	Urine, &c.	$C_{10}H_4N_4O_6$	Wöhler & Liebig
Alloxanic.....	Alkalies and alloxan	$C_8H_2N_2O_8 + 2 HO$	
Mesoxalic.....	Heating alloxanate of baryta	$C_3H_4 + 2 HO$	Do.
Mykomelinic...	Alloxan decomp. by ammonia	$C_8H_5N_4O_5$	Do.
Parabanic.....	Uric acid, &c. with nitric	$C_6N_2O_4 + 2 HO$	Do.
Oxaluric.....	Decomp. of parabanic	$C_6H_3N_2O_7 + HO$	Do.
Thionuric.....	Sulphurous acid and alloxan	$C_3H_5N_3O_8 + 2 HO$	Do.
Uramilic.....	Decomp. of uramile	$C_{16}H_{10}N_5O_{15}$	Do.

Properties of Acids.—Practically speaking, the general properties of acids are the sour taste and the power of changing certain vegetable blue colors, such as litmus, to red. The insoluble acids, such as the silicic, do not of course taste sour, nor change the blues; those slightly soluble may alter the blue color, but not possess the sour taste. Their capability of forming salts by saturating or neutralizing metallic oxides is a more general characteristic than any other. Thus the boracic, although soluble in water, has scarcely a sour taste, and feebly reddens litmus, while it neutralizes bases both in solution and by fusion; its congener, silicic acid, when freshly precipitated, is very slightly soluble in water, and has neither the acid taste nor does it redden litmus, but it neutralizes bases, forming the various kinds of glass, many fluxes, slags, and minerals.

Those which are largely manufactured for the arts are, 1st, *inorganic*, sulphuric, muriatic (chlorohydric), nitric, and arsenious; 2d, *organic*, acetic, citric, oxalic, and tartaric; but a large number are used indirectly, in combination with bases, and many are employed immediately after their production. The sulphuric is by far the most important of all acids, and may be regarded as the key-stone of chemical changes, whether in the laboratory of the scientific chemist or the manufacturer, since it is employed either directly or indirectly in the preparation of nearly all other acids, and of a large proportion of saline and other compounds. The sulphuric and chlorohydric chiefly depend for their use on their powerful affinities, their power of decomposing existing compounds, and abstracting one or more of

their constituents; the nitric is chiefly used for oxidation; the arsenious is variously employed. The organic acids above named are mainly used in dyeing and color-printing. Nearly all acids are employed for uniting with bases to form salts.

ACIDULOUS WATERS. See MINERAL WATERS, *Acidulous*.

ACONITATES. Salts of aconitic acids, few in number and not very interesting.

General formula $At + MO$, for the dry salt, but some contain crystalline water. The alkaline salts are soluble in water and alcohol; imperfectly crystallised. Aconitate of baryta forms a gelatinous precipitate, drying to an amorphous mass, nearly insoluble; formed by adding an excess of barytic-water to the free acid. The salt of silver, formed by adding an alkaline aconitate to nitrate of silver, is white, not wholly insoluble, burning with a puff when heated.

ACONITIC ACID. Formula $C_4HO_3 + aq.$ or $At + aq.$

Discovered by Peschier in the *Aconitum napellus*, and analyzed by L. A. Buchner, Jr. The acid obtained from citric by Berzelius and Dahlstrom appears to be the same; that observed by Braconnot in the *Equisetum fluviatile*, and analyzed by Regnault (equisetic acid), seems also to be identical in its properties, excepting that it may be sublimed without change.

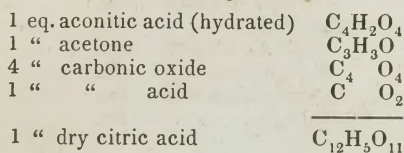
It may be prepared from the above plants by combining it with oxide of lead, decomposing the lead-salt by sulphuretted hydrogen, and purifying the acid by ether. Or it may be

ACONITIC ETHER.

obtained, according to Crasso, by the dry distillation of CITRIC ACID (which see). The residue, dissolved in a little water, and evaporated till a pellicle forms, is mixed with ether; and the acid obtained by evaporating the clear solution dissolved in 5 parts absolute alcohol, and saturated by dry chlorohydric acid gas. Upon the addition of water, the new acid ether (aconitic) separates as a heavy oily liquid; it is mingled with an alcoholic solution of potassa, diluted and precip. by acetate of lead. The insoluble salt of lead is well washed, precip. by sulphuretted hydrogen, and the filtered liquid evapor. to a syrupy consistence, when it congeals to a foliated crystalline mass. Its ethereal solution by spontaneous evaporation leaves a coarse granular, nearly colorless aconitic acid.

It is a white, crystalline mass, soluble in water, alcohol, and ether; of a pleasant acid taste, fuses without decomposition; but by a higher heat is decomposed, and the oily liquid which distills over is the pyraconitic or ITRACONIC ACID (see this).

It is only formed from citric when the latter evolves acetone and carbonic oxide and acid as shown by the following formula.



ACONITIC ETHER. Syn. Aconitate of oxide of ethule. Formed as above. Formula $C_8H_6O_4$, or $C_4H_5O + C_4HO_3$. Sym. AeO, Ät. A colorless, oily liquid, of aromatic odor, resembling oil of calamus, extremely bitter taste; spec. grav. 1.074 at 57.2°; boiling point, 456.8°; partially decomposed by heating above the boiling point, giving off thick, white vapors, and leaving a jet-black, fatty mass in the retort.

ACONITINE. Phar. Chem. A base found in the root and leaves of several species of aconitum, but the *A. napellus* is chiefly employed in medicine, or to extract the base. It exists in the plant in combination with a vegetable acid (probably aconitic?) discovered by Brandes and Peschier. The base prepared by the method of Geiger and Hesse and that by Morson have such a different action on the system, that we must conclude that of the former to be a different base from Morson's, or to be a decomposed product of the latter.

Prep. Dissolve the vegetable salt of aconitine from the root by several boilings with alcohol, and press the residue; distil off the greater part of the alcohol and evap. to an extract; add water, strain it, evap. with gentle heat to a syrup, and add dilute sulphuric acid, which forms sulphate of aconitine. Precip. by ammonia or carbonated alkali, filter, redissolve in dilute sulphuric acid, decolorize the solution by animal coal, filter and reprecip. by alkali, or the base first precipitated is dissolved in alcohol, decolorized by the coal and evaporated. These operations repeated give it perfectly pure. Geiger and Hesse's method con-

ACROLEINE.

sists in adding lime to the 1st alcoholic tincture, removing it again from the clear solution by sulphuric acid, and precipitating the aconitine from the sulphate by carbonate of potassa; it is purified nearly as above.

Prop. Hesse's A. crystallises from aqueous alcohol in white grains, or by evaporating in the air forms a colorless, shining, transparent mass; inodorous, taste at first bitter, then sharp and biting, very poisonous, dilates the pupil of the eye; reacts alkaline, neutralizes acids perfectly; is unchangeable in air, fuses readily, without volatilizing, and by dry distillation yields ammoniacal products; soluble in 50 hot, in 150 cold water, soluble in alcohol and ether. *Lieb., Pog., and Wöhl. Wörterb., vol. i., p. 95.*

Morson's A. is a white, odorless solid, either dull or amorphous, or somewhat sparkling, and apparently crystalline; under the microscope, a triangular form seems to predominate. It readily fuses in a tube, forming a pale, amber colored liquid, not volatile, soluble in alcohol, ether, and the acids. A minute portion, mixed with lard, and applied to the eye, contracts the pupil; $\frac{1}{30}$ of a grain, administered internally has endangered life. It is the most virulent poison known, not excepting prussic acid. *Pereira.*

Its violent effect on the system, its usefulness for neuralgic and rheumatic affections, and the different effects of aconitine prepared in different ways, has led me to devote some space to it. The subject evidently requires close investigation, and it is highly desirable to study its properties in order to simplify its extraction and purification on Morson's plan, whatever that may be, for his aconitine is sold at 75 cts. per grain.

ACONITUM. Bot. A genus of the Order Ranunculaceæ. Species, *Napellus*, *Lycototum*, *Medium Schraderi*, &c. The last analyzed by Bucholz, in 1812, who found in the fresh leaves, water and volatile matter, 83.75; fibre, 6.88; chlorophyll, 1.14; gum, 3.75; soluble veget. albumen, 2.24; extractive matter, with deliquescent acetates and chlorides, 2.81; malate, with a little citrate of lime. Since then, aconitine and aconitic acid have been found in it, the latter of which, united to lime, may have been mistaken for the citrate of lime, or it may have formed from the decomposition of citric acid (see ACONITIC ACID). The volatile acrid matter found in it, which violently affected Bucholz in his experiments, may have arisen from the decomposition of aconitine (?). The plant requires a new and minute examination.

ACROLEINE. Chem. A substance obtained by boiling oils and fats. See FATS AND OILS, action of heat on. When the oily acids are distilled, it is not formed, but the distillation of glycerine yields it in large quantity; it is therefore produced by the dry decomposition of glycerine by heat. It has not been combined with any body from which it can be again obtained, and is not known in a pure state. When the products of distillation of lard or olive oil are collected in a series of well cooled bottles, half-filled with water, the greater part of the volatile acroleine is obtained in the 2d and 3d bottles, in the oil, which floats on the surface, and in the water. By shaking the oil with 20 times its bulk of water, it passes into

the latter, and by distilling the clear water at 125-6° an oily body passes over, soluble in water and with the characteristic odor of acroleine.

It appears to be a very volatile, oily body, with a very pungent odor, attacking the eyes most painfully; characterized by its avidity for the oxygen of the air, when it exhibits an acid reaction. It decomposes even in sealed vessels, or in its aqueous solution, changing gradually into white flocculæ, not at all resembling a fat when dry; inodorous, tasteless, wholly insoluble in and undecomposed by water, ether, sulphuret of carbon, fixed and volatile oils, acids, and alkaline solutions, and scarcely altered by fusing with potassa. A solution of potassa added to the fresh watery solution of acroleine, browns it; acroleine thrown into ether saturated with ammonia instantly loses its odor, and a white ammoniacal compound precipitates, from which it cannot be obtained again.

The presence of acroleine among the products of dry distillation may be viewed as an evidence of the presence of glycerine (oxide of glycerule) in the body distilled.

ACTINOLITE. *Min.* See **HORNBLÉNDE**, *Actinolite*.

ADAMANT. *Min.* A name formerly given to the **DIAMOND**, which see.

ADAMANTINE SPAR. *Min.* See **CO-RUNDUM**.

ADHESION. *Physics.* One of the forces of attraction, called also heterogeneous attraction, to distinguish it from homogeneous attraction or cohesion; for the latter is exerted between similar, adhesion between dissimilar particles of matter. A piece of glass plunged into water and again drawn out retains a portion of water on its surface, is wetted by it, while glass or iron plunged into mercury do not exhibit a similar result; the former shows that there is adhesion between the glass and water, but there is little or none between the two metals, or it is overcome by superior cohesion of iron for iron and mercury for mercury.

Adhesion exerts considerable influence in chemical operations; thus solution, filtration, alloying, cementation, &c., are all, more or less, subject to its control. (The attraction of mercury to other metals, see under **AMALGAM**.) The union of two different bodies, by a cement, exhibits this force; thus when two pieces of wood are joined by corresponding surfaces by the intervention of soft glue, the latter hardens, and draws the surfaces together. In the same way porcelain is united by albumen and lime, bricks and stones by mortar, and the adhesion is often so great that the pieces united will suffer fracture in another direction than in the place of adhesion.

Adhesion is often a troublesome interference in chemical operations. Many precipitates adhere so firmly to a glass vessel, that friction will scarcely remove them, it being often necessary to redissolve and reprecipitate them to obviate the difficulty. The adhesion of fatty bodies to almost every kind of surface renders operations with them tedious and annoying. On the other hand, we may avail ourselves of this force in many cases; thus to prevent a liquid from running down the outside of a vessel while pouring, the lip may be greased,

which, for want of adhesion between the fat and the liquid, keeps the latter in one stream by its cohesive force, and to insure this more certainly in quantitative analysis, a glass rod or tube is laid on the lip, which, by adhesive force between it and the liquid, gives direction to the current. The attraction of moisture from the air by powders and porous substances, has considerable effect on their weight, and hence a powder should be finally weighed just as soon as cool, or cooled over sulphuric acid, &c. See **ANALYSIS**. It is a point of the highest importance in organic analysis, where the content of hygrometric water may entirely change the formula of a substance, since it would give more water and consequently less carbon, &c.

The operation of filtering is dependent on the same force as exerted in capillary attraction, the liquid passing through the pores of paper, &c., independently of pressure, and collecting on the underside in drops, by cohesion. See **FILTRATION**.

Solution of solids in liquids exhibits this attraction and its limits; thus if a piece of loaf sugar be immersed in water by one small point of contact, the water will rise into its pores with some rapidity, until the saccharine cement holding the crystalline particles together is dissolved by the continued exertion of this action, when the mass crumbles and the liquid is saturated. In the solution of sugar, salt, &c., we may conceive the particles of the solid spreading out into spaces between the particles of the liquid, as high as adhesion, diminished by gravity, will allow, and thus a stratum of the solution will remain on the bottom of the vessel, until, by mechanical mixture, they are spread through the whole liquid, and retained there by adhesive force.

That there is a limit to the exercise of adhesion, is evident from the phenomenon of a saturated solution. Thus the adhesion between water and a salt goes on destroying the cohesive force of the latter, until the two opposing forces are nearly balanced, when suddenly there is a cessation of solution, and the liquid is said to be saturated. See **SOLUTION**.

The effect of adhesion between gaseous bodies and solids is often of influence; thus when fine particles of iron, lead, &c., are thrown on water, the portion of air adhering to their surfaces is so great as to prevent their sinking until they have accumulated so that their gravity is superior to the buoyancy of the air. For the interference of the adhesion between air and glass, see **BAROMETER**. It is believed that the adhesion of vapor of water to glass interferes with its vaporization, as steam escapes more freely from metallic surfaces. In the weighing of gases, after the exhaustion of the air in the flask, the gas to be weighed should be admitted several times in order to expel all the atmospheric air, for there can be no doubt that its adhesion to the glass tends to retain a portion, and to alter the exact weight of the gas.

In the article on Absorption, the adhesion of gases and liquids to solids and of gases to liquids is illustrated more fully. The attraction of aqueous vapor from the air by some animal and vegetable substances, has led to their adop

tion to measure the hygrometric condition of the air. See **HYGROMETER**, **HYGROSCOPE**.

The force of heterogeneous adhesion might be measured in many instances, if other forces and circumstances did not modify and diminish its action; we may, nevertheless, approximately determine it. Thus if a dry plug of wood be tightly fitted into one end of a stout tube of glass or porcelain, and a projecting portion be allowed to dip into water, the wood will swell by the entrance of the liquid into its pores so as to burst the tube, though capable of resisting a pressure of more than 700 lbs. to the square inch. This force is also applied to split rocks, holes being bored into them, which are rammed with dry wooden wedges and moistened, so that, by swelling from capillary action, the wood splits the rock in the required direction.

The interfering forces are gravity, cohesion, &c. The solution of salt, &c. in water is opposed by both, the latter more than the former. Heat generally assists adhesion in the case of solution, solids dissolving usually in larger quantities of a heated than a cold liquid. This effect may arise from the fact that heat is an antagonist force of cohesion. On the other hand, heat may diminish it, as in certain solutions (sulphate of soda), &c., or we may destroy the force, as in evaporating a solution to recover a dissolved solid, in distilling where we collect the liquid without the solid. Cold may likewise be employed to separate a solid from solution. See **ATTRACTION**.

ADHESIVE SLATE. *Min.* Contains silica 86.50, alumina 7.00, magnesia 1.50, lime 1.25, oxide of iron 2.50. (*Klaproth*.) Is found massive, and possesses a slaty texture, which becomes visible by exposure; but if the mass be immersed in water, it resumes its former appearance. Has a yellowish or smoke-gray colour; is very soft, splits easily, adheres strongly to the tongue (whence *adhesive slate*), and is opaque. Its specific gravity is 2.08; and it is infusible before the blowpipe. On exposure to a red heat, it becomes brownish, and loses weight. It absorbs water with avidity, but does not fall to pieces. It has hitherto been found only in the gypsum formation around Paris, and is the imbedding substance of the *Menilite*. (*Phillips*.)

ADIPIC ACID. *Chem.* Obtained by Laurent by the oxidation of oleic acid by nitric acid. For its preparation and that of the accompanying acids, see **OLEIC ACID**, *products of oxidation*, and see also **AZOLEIC**, **LIPIC**, **PIMELIC**, and **STERIC** acids.

It crystallises in roundish, sometimes hemispherical, radiated masses, of a brownish color, very soluble in boiling water, of a less sour taste than the pimelic acid, readily soluble

in alcohol and ether; fuses at 266° (293° Bromeis), and congeals on cooling to a mass of long flattened needles; may be distilled over unchanged at a higher temperature.

Laurent's analysis of adipate of baryta gives the equivalent of dry acid 806. Bromeis's later investigations of the same salt, give the dry acid 1800, and from the adipate of silver, 1886.

The formula of Laurent is $C_6H_4O_3$ for the dry, and $C_6H_5O_4 = C_6H_4O_3 + HO$ for the hydrated acid; that of Bromeis is probably more correct, hydrated, $= C_{14}H_9O_7 + 2HO$. Compared with 2 equiv. pimelic acid $C_{14}H_{10}O_6 + 2HO$, it is formed from it by the replacement of 1 eq. hydrogen by 1 eq. oxygen.

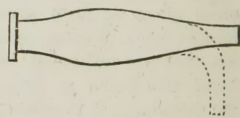
Salts. Adipate of ammonia crystallises in needles. Nearly all its salts appear to be soluble in water, and by not precipitating salts of lead and copper, it is distinguished from pimelic acid. Perchloride of iron precipitates with it of a faint brick-red color. An excess of nitrate of silver throws down from adipate of ammonia a white precipitate.

ADIPOCERE. *Chem.* Fourcroy described under this name a fat derived from corpses, dug from a grave-yard in Paris, which he supposed to be a peculiar fatty body combined with ammonia. Chevreul's investigations proved that it was nothing more than saponified human fat, in which the fat acids were partly free and partly united with ammonia, lime, and magnesia.

ADIPOCERE, MINERAL. *Min.* See **HATCHETINE**.

ADOPTER. *Chem.* Syn. Adapter. *Ger.* Vorstoss. *Fr.* Allonge. An elongated pear-shaped vessel (*Fig. 7*), inserted between a retort and its receiver,

Fig. 7.



the beak of the retort being thrust into and cemented in its larger end, while its smaller end is cemented in the wider neck of the receiver. Sometimes several adopters are connected in a series, and contain a little water to condense gaseous matter, the whole being laid on a gently inclined plane; or the smaller end is curved downwards, as in the dotted line. They are now employed chiefly in France. The Moorish aludel in the reduction of mercurial ores is an earthenware adopter. See **MERCURY**.

ADULARIA. *Min.* See **FELSPAR**.

AEDELFORSITE. *Min.* A red zeolite from Aedelfors, Sweden, described by Retzius, 1818. Fuses and swells before the blowpipe, acting generally like the zeolites. Decomposed by acids forming a jelly. The analysis of Retzius gives in 100 parts

	Found.	Equiv.	Calculated.
Silica	60.280	4	61.46
Alumina	15.416	1	17.09
Lime	8.180	1	9.48
Peroxide of iron	4.160		
Magnesia and Oxide of manganese }	0.420		
Water	11.070	4	11.97
	99.526		100.00

He found that the quantity of peroxide of iron varied, being in another experiment 2.5 per ct.

Formula, $\text{CaO}, \text{SiO}_3 + \text{Al}_2\text{O}_3, 3\text{SiO}_3 + 4\text{aq.}$ ($\text{CS}_3 + 3\text{AS}_3 + 4\text{aq.}$) It is therefore Stilbite less 2 eq. water, or Epistilbite less 1 eq. water. (See these 2 minerals.) v. Kobell mentions aedelforsite as a neutral silicate of lime, evidently not the above, which is a neutral silicate of alumina and lime + 4 water. (*Rammelsberg.*)

AERATED. *Chem.* Obsolete. A body containing carbonic acid; hence *sal aratus*, a term still applied in common life to carbonate of potassa.

AERIFORM BODIES. *Chem. Physics.* Bodies exist in 3 states, as solids, liquids, or aeriform bodies, and the last are divided into vapors and gases. Vapors are characterized by the readiness with which they return to a liquid or solid state at or above ordinary temperature and pressure; thus mercurial vapor condenses readily into the liquid metal, and the vapor of camphor easily returns to its solid state. Gases, on the other hand, are always aeriform at common temperatures, nor can they be rendered liquid or solid without a considerable increase of pressure or reduction of temperature, or both conjoined: some of them have never been condensed, such as oxygen, hydrogen, &c. (See **CARBONIC ACID** for a liquid and solid gas.) The distinction between vapors and gases is not absolute, but one of convenience, for in the only point of difference, the relative forces which they oppose to condensation, they graduate into each other. (See **VAPOR, VAPORIZATION, HEAT, GAS.**) In common with liquids, they are also termed fluids; aeriform bodies are elastic fluids, without cohesive but probably with adhesive force (see **DIFFUSION**); liquids are inelastic fluids, influenced by cohesion. See **LIQUIDS.**

AEROLITE. *Syn.* Meteoric stone. *Ger.* Meteorstein. *Fr.* Aérolithe (Gr. *arg*, the air, and *lithos*, a stone, stone of the air). Certain metallic or stony substances which have sometimes been seen to descend from the air, accompanied with fire and a sound often resembling thunder. They are inflamed globes, which appear instantaneously in the atmosphere, and move through it with extreme velocity, sometimes even equal to that of the earth in its orbit. The direction of their motion is inclined to the horizon. After shining with great splendor for a few instants, they explode with a loud noise, and often at a great height, 30 or 40 miles above the surface of the earth. They do not affect any peculiar direction with respect to the motion of the earth, but seem to come from all points of the heavens indifferently.

The origin of these singular substances is involved in the greatest mystery. Some philosophers, among whom is Laplace, the illustrious author of the *Mécanique Céleste*, suppose them to be ejected from volcanoes in the moon; others suppose them to exist ready formed in the celestial space, circulating about the sun with great velocity, like planets, and falling to the earth when its attraction upon them preponderates; others regard them as fragments of rocks which have been propelled by terrestrial volcanoes to an immense height above the

limits of the atmosphere, and again descend after having described several revolutions about the earth. Albers supposed the small planets, situated between Mars and Jupiter, to be portions of a larger exploded planet, and it might reasonably be conjectured that small portions would be hurled in such directions that they might revolve in irregular orbits, until they come within the sphere of attraction of the planets.

Whatever their external form, magnitude, or appearance, analysis has shown a remarkable similarity in their composition (see below); some of their constituents are also such as are never found similarly united on the surface of the earth; and, moreover, the great quantity of metallic iron, &c. they contain, is almost, if not quite, an anomaly among the mineral substances of the earth.

We may then reject with safety the hypothesis of their earthly origin, and equally that which supposes them to be ready formed and continually revolving in planetary space. That view which supposes their origin in the volcanoes of the moon, seems to be most probable, for no improbable amount of mechanical force would be required. As there is no atmosphere about the moon sufficient to offer a sensible resistance to the motion of a solid body, the force required is only that which would be sufficient to overcome the moon's attraction, which is found by calculation to be about four times the force with which a 24 lb. ball is expelled from a cannon with the ordinary charge of gunpowder. A body projected with a velocity of about 7770 feet per second from the lunar surface, would be detached from the moon, and be brought to the earth by terrestrial gravitation. The calculations of Albers and Poisson have shown it to be a physical possibility. Moreover, the apparent absence of an atmosphere and water on the moon, explains their metallic character. Their uniform composition would lead us to suppose that they generally originated from the same or neighboring volcanoes, and the moon has ever turned one surface to the earth. Pursuing this theory, we might conjecture one portion of the moon to be extremely rich in aerolitic iron and nickel, so that by magnetic force and gravity she would always keep that portion towards the earth.

Whether from the moon or other heavenly bodies, they are intensely interesting, as they convey to us a knowledge of the nature of ponderable matter from other portions of the universe, and enable us to ascertain, to a limited extent, whether other elements exist there, or whether, as the phenomena of gravity are the same through the universe, the nature of ponderable matter remains likewise the same. Guided by these considerations, Berzelius was led to apply his chemical skill and acute observation to their thorough investigation. He observes, that although we have not yet found all the elements of the earth in aerolites, yet we have in them those which are more abundantly diffused, and we have also succeeded in determining the nature of their chemical union.

Instead of analyzing an aerolite as a whole, as others had usually done, he found that they

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consisted of several distinct combinations, which he separately analyzed. After the metallic portions were carefully removed by a magnet, the remaining earthy matter consisted of 2 portions, one *soluble*, the other *insoluble* in

chlorohydric acid. The first of the two following aerolites fell on 25th Nov., 1833, at Blansko, in Moravia; the 2d, on 5th Aug., 1812, near Chantonay, Vendée, France; the 3d fell near Lontalax, in Finland.

Soluble Mineral.	1. Blansko.	Oxygen.	2. Chanton- nay.	Oxygen.	3. Lontalax.	Oxygen.
Silica	33.084	17.192	32.607	16.96	37.411	19.44
Magnesia.....	36.143	14.00	34.357	13.29	32.922	12.74
Protoxide of iron....	26.935	6.01	28.801	6.56	28.610	6.51
“ manganese	0.465	0.12	0.821	0.19	0.793	0.17
Oxide of nickel, con- taining copper and tin	0.465	0.10	0.456		Al.0.264	0.12
Alumina	0.329	0.10				
Soda	0.857	0.12	0.977		Traces	Copper, Tin, Potassa, Soda.
Potassa.....	0.429	0.07				
Loss	1.273		1.971			

Insoluble Mineral.	1. Blansko.	Oxygen.	2. Chanton- nay.	Oxygen.
Silica	57.012	29.626	56.252	29.75
Magnesia	24.956	9.660	20.396	7.91
Lime.....	1.437	0.412	3.106	0.88
Protox. iron	8.362	1.904	9.723	2.21
Protox. manganese.....	0.557	0.124	0.690	0.16
Oxide of nickel, contains oxides of copper and tin.....	—	14.338	0.138	0.05
Alumina	4.792	2.238	6.025	2.81
Soda .....	....		1.000	0.26
Potassa	—		0.512	0.08
Chromic iron (with tin).....	1.306		1.100	
Loss	1.579		1.070	

Meteoric Iron abstracted by the Magnet.

	1. Blansko.	4. Pallas iron.	5. Elbogen.
Iron	93.816	88.042	88.231
Nickel.....	5.053	10.732	8.517
Cobalt.....	0.347	0.455	0.762
Tin and copper.....	0.460	0.066	—
Magnesium.....	—	0.050	0.279
Manganese	—	0.132	
Sulphur.....	0.324	trace	trace.
Carbon.....	—	0.043	
Insoluble residue.....	—	0.480	Phosphurets, 2.211

No. 4 is from the celebrated mass of meteoric iron found by Pallas, in Siberia. No. 5 has been long preserved in the City Hall, at Elbogen, and fell about the beginning of the 15th century. The insoluble residues of these two subjected to separate analyses were found to consist of phosphurets, and to agree closely with the phosphurets of Bohumilz iron, formerly analyzed by Berzelius. (*Pogg. Ann. B. xxvii.*) They have the following percentage composition.

	Pallas iron.	Elbogen.	Bohumilz.
Iron.....	48.67	68.11	65.977
Nickel ...	18.33	17.72	15.008
Magnesium.	9.66		Silicium 2.037
Phosphorus.	18.47	14.17	14.023
Loss	4.87	not calculated.	Car. 1.422

The earthy mineral accompanying the Pallas iron, called Pallas-olivine, consisted of

	Oxygen.
Silica.....	40.86
Magnesia.....	47.35
Protoxide of iron....	11.72
Protox. of manganese.	0.43
Oxide of tin	0.17

The above analyses will give a correct idea of the usual character and composition of the aerolites that have been subjected to analysis, with the exception of 3, which fell near Stannern, in Moravia, and near Jonzac and Juvenas, in France, and which closely resemble each other. Their analysis, by Klaproth and Lavi-gier, gives the following composition:

	Stannern.	Jonzac.	Juvenas.
Silica	48.25	46.00	40.0
Magnesia	2.00	1.60	0.8
Lime.....	9.50	7.50	9.2
Protoxide of iron.	23.00	32.40	23.5
Alumina.....	14.50	6.00	10.4

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	Stannern.	Jonzac.	Juvenas.
Oxide of manganese	—	2·80	6·5
Potassa.....	—	—	0·2
Oxide of copper...	—	—	0·1
Oxide of chrome...	—	1·00	1·0
Sulphur.....	2·75	1·50	0·5

They differ from the preceding in containing no metallic iron, in being an aggregate of several minerals, which are readily distinguished, and in containing a very small quantity of magnesian silicate. G. Rose has shown that they are probably a mixture of Labradorite and Augite, with some magnetic pyrites free from iron. It is therefore probable that they are from a different source from the majority of aerolites, and probably, admitting their lunar origin, from another part of that body from which they are not often thrown in such direction as to come within the sphere of the earth's attraction. This, with their want of metallic iron, lends strength to the hypothesis of the moon's constantly presenting the same surface to the earth.

A stone fell on 15th March, 1806, near Alais in France, which was also examined by Berzelius. It contained soluble and insoluble matter; the latter consisted in part of magnetic oxide of iron, a little sulphuret and metallic iron without nickel, in part of olivine, a grayish-brown substance which was sublimed (unknown), carbon and water. The soluble matter consisted of sulphates of magnesia, lime, potassa, soda, and nickel, with a trace of copper.

The minerals which have been determined as constituents of aerolites are:

1. *Native Iron*, which often constitutes nearly the whole mass.

It is partly mingled with other metals, chiefly nickel, and partly forms an alloy with this metal, which, by etching with acid, exhibits a crystalline structure.

The insoluble residues, often crystalline in structure, are evidently phosphurets of iron, nickel, and magnesium; but their exact composition has not yet been determined.

2. *Sulphuret of Iron*. It is probably a compound of 1 eq. of each, but the intimate mixture of nickel-iron has prevented a determination of this point.

3. *Magnetic Iron Ore*. It is the only substance extracted by the magnet from the aerolite of Lontalax, and was found also in one from Alais.

4. *Chromic Iron*. This is an almost universal accompaniment of aerolites, although existing in them in very small quantity.

5. *Oxide of Tin*. Tin exists in aerolites, not only in the iron, &c., but also as the oxide of tin, containing a trace of copper.

6. *Meteorite Olivine* is the soluble mineral, and constitutes about $\frac{1}{3}$ of the mass remaining after extracting the magnetic particles. It has precisely the composition of the several varieties of common olivine, being $\frac{1}{3}$ basic silicate of magnesia and protoxide of iron, $\frac{3 \text{ MgO}}{3 \text{ FeO}} \left\{ \text{SiO}_3 \right\}$, replaced, as in common olivine, by small quantities of silicate of nickel and manganese, and like it containing oxide of tin. See OLIVINE.

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The excess of oxygen in the bases of the aerolites from Blansko and Chantonay is due to the fact that all the iron is represented as oxide, while a portion was evidently sulphuret, so that the oxygen in bases and acid would be about equal, as shown in the Lontalax specimen.

7. *Insoluble Silicates*, of magnesia, lime, protoxides of iron and manganese, alumina, potassa and soda. The oxygen in the acid is twice that in the base, so that viewed as a whole it is $\frac{2}{3}$ silicate, but it is not unlikely composed of at least two minerals, an augitic and leucitic. The former would be $3(\text{MgO} + \text{CaO} + \text{FeO})$, 2 SiO_3 , and the leucitic $(3 \text{ MgO} + \text{CaO} + \text{NaO} + \text{KO})$, $2 \text{ SiO}_3 + 3 (\text{Al}_2\text{O}_3, 2 \text{ SiO}_3)$; or representing the metallic bases by M, the 1st is 3 MO , 2 SiO_3 , and the 2d, 3 MO , $2 \text{ SiO}_3 + 3 (\text{M}_2\text{O}_3, 2 \text{ SiO}_3)$.

To these we may add the sulphates of the stone of Alais.

The elements heretofore found in aerolites are oxygen in oxides, hydrogen in a soluble organic compound in the stone from Alais, sulphur in sulphuret and sulphates, phosphorus, carbon, silicium in the silicates, chrome, tin, copper, cobalt, nickel, manganese, and iron; aluminum, magnesium, and calcium are common oxides in aerolites, sodium and potassium in small quantity. These 18 elements are nearly $\frac{1}{3}$ of those found on the earth. Others are supposed to have been detected, but their existence requires confirmation, excepting perhaps the content of chlorine found by Jackson in the meteoric iron from Clarke county, Alabama. It is the first instance of a halogen in meteoric iron, and should be closely investigated to ascertain whether it must be ascribed to the aerolite.

Viewing aerolites as bodies showing the composition of another planet, the great quantity and peculiar character of the native iron is remarkable. The excess of magnesia, the rarity of silica, and the small amount of silicates of alumina and alkali are characteristics, and exhibit the reverse of the surface of our earth. The aerolite of Alais shows that in the place whence it originated the mineral substances disintegrated, and that this took place with the formation consisting of olivine and native iron. The carbonaceous matter does not prove that organic nature exists where it originated. See Berzelius in *Pogg. Annalen*, Bd. xxxiii.

AERONAUTICS. *Chem. Phys.* The art of navigating the air. The movement of birds through the air might naturally lead men to believe that the artificial navigation of the air was not much farther removed from human power and skill than sailing on the water; accordingly we may trace in very ancient fables the attempts which were made to attain so desirable an object, although we may withhold credence from their success. It was not until the rise of chemical science, towards the close of the last century, that the attempt was in any degree successful. The 1st method was to expand the air in a balloon by fire under an opening in the bottom (1782); the 2d, in 1783, consisted of a closed balloon filled with hydrogen; and 3d, within the few last years they have

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been filled with illuminating gas (carbohydrogen); the 4th attempt consists of a car with very large horizontal wings, the paddles under or about the car being worked by a steam engine. I doubt its success. See **BALLOON**.

AEROSTATION. A term incorrectly applied to aeronautics, excepting to the 4th attempt (see above).

AETHAL AND AETHALIC ACID. See **CETULE, CETULIC ACID, and SPERMACETI.**

AESCHYNITE. *Min.* (*Αισχυνή*, modesty.) *Physical.* System, right rhombic. Prism about 127° and 53° . (*Brooke*.)

$H = 5$ to 6 : spec. grav. $5.14-5.55$.

Comb. The octohedron terminating the prism. Color, nearly black, inclining to brownish-yellow when translucent; lustre, resinous; streak, dark gray, nearly black; fracture, small sub-conchoidal, translucent on edges, when in very thin fragments.

Chem. Reaction. In a bulb, gives water, in open tube, strong evidence of fluohydric acid; on charcoal or in forceps, swells and becomes rust-yellow, infusible, forms a black slag on the extreme edges; dissolves in borax dark yellow; a little in mic. salt colorless, with more, yellow, which becomes cloudy, dark brown to violet in reducing flame, particularly by adding tin; decomp. by soda without fusion, leaving a rust-yellow mass.

Analysis. Hartwell's Analysis gives Titanic acid, $56.0 + \text{Zirconia}$, $20.0 + \text{Peroxide of cerium}$, $15.0 + \text{Lime}$, $3.8 + \text{Peroxide of iron}$, $2.6 + \text{Peroxide of tin}$, $0.5 = 97.9$. Titanic acid and Zirconia are not accurately given, from the difficulty of separating them. *Pogg. An.* xvii. and *Rammelsberg*.

AFFINITY. *Chem.* Syn. Chemical affinity or Attraction, Elective attraction. *Ger.* Chemische Verwandtschaft oder Anziehungskraft, Wahlverwandtschaft, Wahlanziehung, Affinität. *Fr.* Affinité.

That variety of attraction which is exerted between different kinds of matter, at insensible distances, uniting them into a new body, possessed of properties essentially different from those of its constituents. By acting only at insensible distances, it is sufficiently distinguished from gravity; exerted only between different kinds of matter, it is very different from cohesion; but it is more difficult to draw a narrow line of demarkation between affinity and that form of attraction which is usually placed under Heterogeneous adhesion, viz. the attraction evinced in solution, for the latter seems to form a connecting link between chemical and other kinds of attraction. See **SOLUTION**. The latter part of the above definition, that "it forms bodies essentially different," will serve to distinguish it from attraction in solution.

Affinity is not always exerted between bodies; thus fluorine does not combine with oxygen, but readily with metals. Carbon does not unite with mercury, but combines with oxygen, iron, &c. It is therefore elective in its character, preferring one body to another. Such a view, however, is only in accordance with the present state of the science, for it is possible that each element may combine with each of the others; but that other forces interfere with the exercise

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of affinity. Thus nitrogen may have a strong attraction for the metals, and the reason why such compounds are difficult to make and easily decomposed, may be the highly elastic state of nitrogen.

As far as we know, it acts at insensible distances, but it is possible that the distance to which its energy extends may be measured. Thus the union of some bodies by friction, when in a minute state of mechanical division, seems to hint at a sensible distance of action.

I. CONDITIONS AND CIRCUMSTANCES OF COMBINATION BY AFFINITY.

Affinity must be sufficiently powerful to overcome the opposing forces of gravity, cohesion, and elasticity. The bodies must be in immediate contact, since the action is at insensible distances. It is rarely sufficient to pulverize two solids, however fine, to induce their chemical union, for their particles do not admit freely of motion, but by constant and rapid trituration many points of surface are brought in contact nearly at one time, and combination may ensue; in this manner sulphur and finely divided copper unite with the evolution of heat. The affinity of bodies is, therefore, promoted by every thing which tends to their close approximation; in solids, by their pulverization and intermixture, this attraction residing in the ultimate particles of bodies; in gases, by their spontaneous diffusion through each other, which occasions a more complete intermixture than is attainable by mechanical means; and between liquids, or between a liquid and solid by the adhesive attraction which liquids possess, which must lead to perfect contact, and also by a disposition of liquid bodies to intermix, of the same physical character as gaseous diffusion. Elevation of temperature has certainly often a specific action in increasing the affinity of two bodies, but it also often acts by producing a perfect contact between them, from the diffusion or vaporization of one or both bodies. Hence, no practice is more general to promote the combination of bodies than to heat them together. Thus fused sulphur does not unite with carbon, but must be brought in the vaporous state, in contact with carbon: effloresced carbonate of soda absorbs carbonic acid at first, slowly; but more rapidly in proportion as absorption develops heat, until at length its absorption is violent. Carbon, iron, &c., must be heated in oxygen to develop their affinity for it.

Light may frequently induce union like heat; thus chlorine with hydrogen or carbonic oxide. Electricity may also unite gases by heat or compression, as hydrogen and oxygen, &c. The expansion of a gas often assists affinity; thus phosphorus exhibits slow combustion in oxygen at a lower temperature, the more the gas is expanded. Condensation frequently effects union by the heat it develops, and by bringing the particles in closer contact. (*Gmelin, &c.*)

If the affinity between two gases is sufficiently great to begin combination, the process is never interrupted, but is continued from the diffusion of the gases through each other till complete, or at least till one of the gases is entirely con-

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sumed. Thus when hydrochloric acid and ammoniacal gases, in equal measures, are introduced into a jar containing at the same time a large quantity of air, the formation of hydrochlorate of ammonia proceeds, the gases appearing to search out each other, till no portion of uncombined gas remains. The combination of two liquids, or of a liquid and a solid, is also facilitated in the same manner by the mobility of the fluid, and proceeds without interruption, unless, perhaps, the product of the combination be solid, and by its formation interpose an obstacle to the contact of the combining bodies. But the affinities of two solids which are not volatile, are rarely developed at all, owing to the imperfection of contact. Even the action of very powerful affinities between a solid and a liquid or a gas, is often arrested in the outset from the physical condition of the former. Thus the affinity between oxygen and lead is certainly considerable, for the metal is rapidly converted into a white oxide, when ground to powder and agitated with water in its usual aerated condition; and in the state of extreme division in which lead is obtained by calcining its tartrate in a glass tube, the metal is a pyrophorus, and combines with oxygen when cold, with so much avidity as to take fire and burn the moment it is exposed to the air. Iron also, in the spongy and divided state in which it is procured by reducing the peroxide by means of hydrogen gas at a low red heat, or by treating the oxalate in a tube, absorbs oxygen with equal avidity at the temperature of the air, and takes fire and burns. But notwithstanding an affinity for oxygen of such intensity, these metals in mass oxidate very slowly in air, particularly lead, which is quickly tarnished indeed, but the thin coating of oxide formed does not penetrate to a sensible depth in the course of several years. The suspension of the oxidation may be partly due to the comparatively small surface which a compact body exposes to air, and which becomes covered by a coat of oxide, and protected from farther change; but partly also to the effect of the conducting power of a considerable mass of metal in preventing the elevation of temperature consequent upon the oxidation of its surface; for metals oxidate with increased facility at a high temperature, such as the lead pyrophorus quickly attains from the oxidation of the great surface which it exposes, compared with its weight. The heat from the oxidation of the superficial particles of the compact metal, however, is not accumulated, but carried off and dissipated by the conducting power of the contiguous particles, so that elevation of temperature is effectually repressed. It thus appears that the state of aggregation of a solid may oppose an insuperable bar to the action of a very powerful affinity.

Contact. The affinity of two bodies, one or both of which are in the state of gas, is often promoted in an extraordinary manner by the contact of certain solid bodies. Thus oxygen and hydrogen gases may be mixed and retained for any length of time in that state without exhibiting any affinity for each other, and the gaseous mixture may, indeed, be heated in a glass vessel to any temperature short of red-

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ness, without showing any disposition to combine. But if a clean plate of platinum be introduced into the cold mixture, the gases in contact with the metallic surface instantly unite and form water; other portions of the mixture come then in contact with the platinum and combine successively under its influence, so that a large quantity of the gaseous mixture may be quickly united. (*Graham.*) See **CATALYSIS AND CONTACT.**

Nascent State. Chemical combination of two bodies seems often to take place only by the co-affinity of other bodies with each other. Thus nitrogen and hydrogen gases do not form ammonia by direct union, but by the oxidation of tin by nitric acid or by nitric oxide and water; the metal abstracts oxygen both from the water and nitrous body, evolving nitrogen from the latter and hydrogen from the water, which, in their then nascent state, combine to form ammonia. Such combinations of bodies in their nascent state are very numerous, and we are unable to produce a large number of them in any other way; such, for example, are numberless artificial compounds, developed in the province of organic chemistry.

Inducing or Imparted Affinity. There is another singular operation of affinity allied to the preceding, which is not well understood. It may be termed inducing, inductive, or imparted affinity. Attention was drawn to it by Liebig, in a general way, who classified some of the facts by the law, that a body while in the act of combining has the power of imparting the same action to another body in contact with it, inducing it to unite with a third body, when it would not have done so under similar circumstances, without such contact. Nitrogen and oxygen do not unite by heat, and indeed difficultly in any way; but hydrogen burned in the air produces water containing nitric acid; platinum is wholly insoluble in, and not oxidized by nitric acid when alone, but it is so when alloyed with silver. This interesting subject is deserving of a full and extended investigation, which would unquestionably lead to a much more thorough knowledge of the operations of affinity than we at present possess.

II. COMBINING PROPORTIONS.

Combination by Weight. Analysis has shown that the composition of bodies is fixed and invariable; thus 100 parts by weight of water are uniformly composed of 88.9 oxygen and 11.1 hydrogen (or 8 to 1); whether the water be distilled from rain, springs, rivers, &c., or formed artificially, by burning oxygen and hydrogen in any proportion. If we observe the measure of the two gases, that is the bulks which 88.9 and 11.1 parts respectively occupy, we are struck with the remarkable fact that there is exactly twice as much hydrogen as oxygen. Nature here points out a very simple proportion where two gases unite; but the greater number of substances are only known in a solid or liquid state, where their union by measurement cannot as well be observed. The former is called combination by weight, the latter by volume; and although the composition of a body is usually expressed by

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weight, yet we are frequently led to the result by an examination of their combination by volume. The numbers expressing these two modes of combination are very different. If we examine several bodies containing one element in common, we find, what may be

inferred from the composition of water, that that element unites with very different quantities of other elements. Thus, in the following table the ratio of oxygen to the other constituent is very different:

Composition of Oxides.

Water.	Oxide of Copper.	Oxide of Zinc.	Oxide of Lead.	Oxide of Silver.
Oxygen....88.9 Hydrogen. 11.1	Oxygen.... 20.2 Copper.... 79.8	Oxygen.....19.1 Zinc.....80.9	Oxygen.....7.2 Lead..... 92.8	Oxygen....6.9 Silver.... 93.1
100	100	100	100	100

But the relation between the oxygen and the other constituent in these oxides will be seen more distinctly by stating their composition in

such a way as to have the oxygen expressed by the same number in every case, or made equal to 8 parts. Thus,

Water.	Oxide of Copper.	Oxide of Zinc.	Oxide of Lead.	Oxide of Silver.
Oxygen...8 Hydrogen.1	Oxygen... 8 Copper.. 31.7	Oxygen..... 8 Zinc..... 32.3	Oxygen..... 8 Lead.....103.7	Oxygen..... 8 Silver.....108.3
9	39.7	40.3	111.7	116.3

It therefore follows that 8 parts of oxygen
Combine with 1 part of hydrogen,
31.7 parts of copper,
32.3 “ “ zinc,
103.7 “ “ lead,
108.3 “ “ silver.

These numbers seem to belong to the sub-

stances to which they are attached; for when the compounds of sulphur with the same bodies are examined, the same numbers are obtained as shown by the following table; the only difference being, that the quantity of sulphur is rather more than twice that of the oxygen.

Composition of Sulphurets.

Of Hydrogen.	Of Copper.	Of Zinc.	Of Lead.	Of Silver.
Sulphur.. 16.1 Hydrogen. 1	Sulphur....16.1 Copper ....31.7	Sulphur....16.1 Zinc.....32.3	Sulphur....16.1 Lead.....103.7	Sulphur....16.1 Silver.....108.3
17.1	47.8	48.4	119.8	124.4

In the same manner 35.4 parts of chlorine combines with 1 hydrogen, 31.7 copper, 32.3 zinc, 103.7 lead, 108.3 silver; and indeed if a large number of bodies be examined, the same remarkable relation is observed. (*Graham.*)

Now it is evident that we might express the composition of all bodies by per centages, as in the 1st table above given; but the 2d and 3d reveal to us a certain fixed numerical relation between the weights in which bodies combine, and which the memory can retain more easily than the variable numbers of percentage composition. For the sake of uniformity there should be a standard or unit of comparison, which once adopted, fixes a particular number to every substance. Such numbers are called the Combining Proportions, Combining Weights of Bodies, Equivalent Numbers, Equivalents, Atomic Weights. The elements of water are each taken as unity for equivalents or combined weights, just as water itself is assumed as unity for the specific weights of bodies, and hence arise two series of equivalents according as hydrogen or oxygen is employed as the unit of comparison. In the one, hydrogen is assumed as unity; in the other, oxygen is assumed to be 100. The following table of

the substances introduced above will show the relation between the 2 series.

	H = 1	O = 100
Hydrogen 1 equivalent	1 or	12.5
Oxygen 1 equiv.	8 “	100.0
Sulphur 1 “	16.1 “	201.1
Copper 1 “	31.7 “	395.7
Zinc 1 “	32.3 “	403.2
Chlorine 1 “	35.5 “	443.75
Lead 1 “	103.7 “	1294.5
Silver 1 “	108.3 “	1351.6

These proportional numbers belong to one proportion of the body to which they are attached, and in the present work they are usually termed *equivalents* and their numbers *combining weights*; thus, 1 eq. oxygen has a combining weight of 8 by the hydrogen scale, or 100 by the oxygen scale, and so of each of the others.

See under **EQUIVALENTS** for a general table of the combining weights of all the elements, and under each substance of importance for its equivalent by both series. The hydrogen scale is preferred in the present work, according to which the combining weight of a simple substance is the quantity of it which unites with 8

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parts of oxygen to form a protoxide or a strong base.

There are 2 laws of combination to which the preceding remarks lead us. The first is that *bodies unite with each other by proportional numbers which become fixed when referred to a standard of unity, and are called equivalents or combining weights.*

The 2d law, deducible from the 1st, is that *where bodies unite in more than one proportion, they*

combine in simple multiples of their equivalents, and in no intermediate proportions. There are at least two series of combinations embraced in this law.

1st Series. A unites with 1, 2, 3, 4, 5, &c. of B.

2d Series. A unites with 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, &c. of B.

The first series is exemplified by the subjoined compounds.

Water is composed of.....	Hydrogen 1	Oxygen 8	1
Binoxide of hydrogen.....	do. 1	do. 16	2
Carbonic oxide.....	Carbon 6	do. 8	1
Carbonic acid.....	do. 6	do. 16	2
Nitrous oxide.....	Nitrogen 14·19	do. 8	1
Nitric oxide.....	do. 14·19	do. 16	2
Nitrous acid.....	do. 14·19	do. 24	3
Hyponitric acid.....	do. 14·19	do. 32	4
Nitric acid.....	do. 14·19	do. 40	5

In all these compounds the ratio of the oxygen is expressed by whole numbers. In water the hydrogen is combined with half as much oxygen as in the binoxide of hydrogen, so that the ratio is as 1 to 2. The same rela-

tion holds in carbonic oxide and carbonic acid. The oxygen in the compounds of nitrogen and oxygen is in the ratio of 1, 2, 3, 4 and 5.

The following compounds exemplify the second series:—

Protoxide of iron consists of iron.....	27·18	Oxygen 8	1
Peroxide..... do.....	27·18	do. 12	$1\frac{1}{2}$
Protoxide of manganese Manganese....	27·72	do. 8	1
Sesqui-oxide..... do.....	27·72	do. 12	$1\frac{1}{2}$
Bin-oxide..... do.....	27·72	do. 16	2
Sulphurous acid..... Sulphur.....	16·12	do. 16	2
Hyposulphuric acid..... do.....	16·12	do. 20	$2\frac{1}{2}$
Sulphuric acid..... do.....	16·12	do. 24	3

Instead, however, of expressing the combinations of B by $1\frac{1}{2}$, $2\frac{1}{2}$, &c., by doubling the two elements, the 2d B will be in whole numbers; thus the peroxide of iron will be 2 eq. iron = $27·18 \times 2 = 54·36$ and 3 eq. oxygen = $8 \times 3 =$

24, and hyposulphuric acid = 2 eq. sulphur with 5 eq. oxygen.

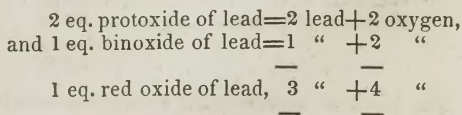
The number of equivalents which may enter into a compound, is subject to considerable variation, as will appear from the following examples:

One equiv. oxygen	+	One equiv. hydrogen	form water.
Two equivs. oxygen	+	One " hydrogen	" peroxide of hydrogen.
One equiv. oxygen	+	Two equivs. copper	" suboxide of copper.
One " sulphur	+	Three " oxygen	" sulphuric acid.
Two equivs. sulphur	+	Two " oxygen	" hyposulphurous acid.
Two " iron	+	Three " oxygen	" peroxide of iron.
Two " sulphur	+	Five " oxygen	" hyposulphuric acid.
Two " manganese	+	Seven " oxygen	" hypermanganic acid.

Representing the constituents of a binary compound by A and B, the last being the oxygen or electro-negative constituent, the most frequent combination is $A + B$, then $A + 2B$, $A + 3B$, and $A + 5B$. The combination of $2A + 3B$, is not unfrequent, but $2A + B$, $A + 4B$, $A + 7B$, $2A + 2B$, or $2A + 5B$ are of comparatively rare occurrence. Combination between two elements is not known to occur in more complicated ratios than the preceding, if the compounds of carbon and hydrogen be excepted, which are numerous and exhibit great diversity of composition, like the compounds of organic chemistry generally, to which they properly belong.

There are cases of combination where it would seem at first sight that the 2d law may not hold good as far as regards the simplicity of multiples, for there are many compounds, which do not fall into either of the above

series, such for example are the red oxide of lead, two of the oxides of manganese, &c. But the former, which consists of 1 eq. lead united with $1\frac{1}{2}$ eq. of oxygen, or 3 eq. to 4 oxygen, has been explained by supposing that it is composed of 2 oxides of lead, thus,



A similar explanation has been given of other oxides. The two lately discovered acids of sulphur fall into the same series. Langlois' sulphuretted hyposulphuric acid is composed of 3 eq. sulphur and 5 oxygen; but it may be supposed to consist of sulphuric and hyposulphurous acids, that is

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1 eq. hyposulphurous acid	=	2 sulphur	+	2 oxygen.
1 " sulphuric acid	=	1 " "	+	3 " "
1 " Langlois' acid	=	3 " "	+	5 " "

Of the correctness of such suppositions, the decomposition of these bodies affords strong presumptive evidence, for the oxides most readily separate into the more definite oxides, and the above acid easily separates into the two more definite acids.

Ternary or more complex compounds. It follows from the 1st law that the combining weight of a compound body must be the sum of the combining weights of its constituents. Hence, when three or more elements are united in two sets, or 2 binary compounds, these unite also by equivalents. Thus, oil of vitriol containing sulphur, oxygen and hydrogen, consists more immediately of sulphuric acid and water in the proportion of

1 equiv.	water	9
1 equiv.	sulphuric acid	40·12 = 49·12

Of which the compound water has a combining weight of 9 (or 1 eq. oxygen, 8 + 1 eq. hydrogen 1), and the acid has a comb. weight of 40·12, that is, 1 eq. sulphur, 16·12 + 3 eq. oxygen (8 × 3) 24. The combining weight of oil of vitriol is therefore 49·12.

The combining weight of oxide of zinc is 40·31, the sum of oxygen 8, and zinc 32·31, and the compound of this oxide with sulphuric acid, or the salt, dry sulphate of zinc, consists of

Oxide of zinc.....	40·31
Sulphuric acid.....	40·12
	80·43

80·43 being the combining weight of dry sulphate of zinc.

Of potassa, the combining weight is 47·26, or oxygen 8, added to potassium 39·26, and to this weight of potassa, the usual weight of sulphuric acid is attached in the sulphate of potassa, which is composed of

Potassa.....	47·26
Sulphuric acid.....	40·12
	87·38

Of these salts themselves, the combining weights ought to be the sums obtained by the addition of the numbers of their constituents; and accordingly the double sulphate of zinc and potassa consists of

Sulphate of zinc.....	80·43
Sulphate of potassa.....	87·38
	167·81

The last sum expresses the combining weight of the double salt.

Of nitric acid the constituents are 1 equiv. of nitrogen, 14·19, and 5 equivs. of oxygen, 40, making together 54·19, which is the combining weight of that acid, and is found to unite with 9 water, with 40·31 oxide of zinc, and with 47·26 potassa, or with the same quantities of these oxides as combine with 40·12 sulphuric acid. Carbonic acid is composed of 1 equiv.

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of carbon 6, and 2 equiv. of oxygen 16, so that its combining weight is 22, in which proportion it unites with 47·26 potassa, to form the carbonate of potassa. The equivalent quantities of all other acids and bases correspond in like manner with the numbers deducible from their composition. Indeed the law is found to hold in compounds of every class and character, whether they contain few or many equivalents of their elements. Thus of the vegeto-alkali morphia, which contains a large number of equivalents (see MORPHIA), the combining proportion is the high number 292·19, which is the sum of 35 equivs. of carbon 210, 20; equivs. of hydrogen 20; 1 equiv. of nitrogen 14·19, and 6 equivs. of oxygen 48; 292·19 morphia being found to unite with 40·12 sulphuric acid, or a combining weight of that acid, to form the sulphate of morphia.

Compound bodies likewise unite among themselves in multiples of their combining weights, as well as in single equivalents. Thus 47·26 potassa combine with 52·19 chromic acid, and with double that quantity, or 104·38 chromic acid, to form the yellow and the red chromates of potassa; the first containing 1 equiv. and the second 2 equivs. of acid. The occurrence of multiple proportions was well illustrated by Dr. Wollaston in the carbonate and bicarbonate of potassa. A quantity of the latter salt being divided into equal parts, one half was exposed to a red heat, by the effect of which the salt lost some carbonic acid and became neutral carbonate, and both portions being afterwards decomposed by an acid, the salt in its original condition was found to afford a measure of carbonic acid gas exactly the double of that yielded by the portion exposed to the high temperature. By experiments equally simple and convincing, he proved that in the three salts formed by oxalic acid and potassa, the quantities of acid which combine with the same quantity of alkali are rigorously among themselves as the numbers 1, 2, and 4. The composition of all other super and sub salts is found to be in conformity with the same law, one of the constituents being always present in the proportion of 2 or more equivs. See SALTS, the table of ACETATES, &c.

Bodies likewise *replace* each other in combination, in equivalent quantities. Thus in the decomposition of water by chlorine, which occurs in certain circumstances, 35·5 parts of chlorine unite with 1 hydrogen, or 1 equiv. of that body, to form hydrochloric acid, and displace at the same time and liberate 8 parts of oxygen. Hence the number 35·5 represents the combining weight of chlorine which is equivalent in combination to, or can be substituted for 8 oxygen. Again, in decomposing hydriodic acid, 35·5 chlorine unite with 1 hydrogen, and liberate 126·5 iodine, which equivalent of iodine may again acquire 1 hydrogen by decomposing sulphuretted hydrogen and set

free 16.1 sulphur. Hence 126.5 and 16.1 are the equivalent quantities of iodine and sulphur, which take the place of 35.5 chlorine, or 8 oxygen, in combination with 1 hydrogen. When 32.3 parts of zinc are introduced into a solution of nitrate of copper, they dissolve, acquiring 8 oxygen, and 54.19 nitric acid, and become nitrate of zinc, while 31.7 parts of metallic copper or 1 equiv. are deposited, which had previously been in the state of nitrate and in combination with the above-mentioned quantities of oxygen and nitric acid, and the solution remains otherwise unaltered. Zinc throws down nearly all the metals from their solutions in acids in the same manner, and if the quantity of this substance introduced into the solutions and dissolved be its combining weight, as in the instance given, the quantities of the metals precipitated will also be combining weights of those metals. The quantity of zinc employed may be varied, but the quantity of other metal precipitated will still be to the quantity of zinc dissolved, in the ratio of the combining weights of the two metals. Lead, copper, tin, or any other metal, when it acts like zinc as a precipitant, likewise throws down equivalent quantities of other metals, and takes their place in the pre-existing compound. The substitution in a saline compound of one metal for another, which thus occurs, without any change in the character of the

compound, shows how justly the combining proportions of bodies are also termed their equivalent quantities or equivalents. The metal displaced, and that substituted for it, have evidently the same value in the construction of the compound, and are truly equivalent to each other. (*Graham.*)

2. *Combination by volume.* Frequently termed theory of volumes. It was observed at the commencement of the section on combination by weight, that water was differently composed by weight or volume, and that the latter offers a very simple ratio. A closer examination of the subject exhibits a close agreement between the laws governing combination by weight and volume.

Humboldt and Gay-Lussac first observed that hydrogen and oxygen unite to form water in the exact ratio of 2 to 1; and the latter, pursuing his investigations with other gases and with vapors, discovered that the principles deducible from that fact admitted of general application to such bodies. He proved in his essay on the "combination of gaseous substances with each other," that they unite by volume in very simple ratios. The following views are such as either were established by Gay-Lussac, or the results of subsequent investigations.

1. Gases and vapors unite in the simple ratio of 1 to 1, 1 to 2, 1 to 3, &c. Thus,

100 vols. hydrogen	+ 50 vols. oxygen	= water.
100 " ammoniacal gas	+ 100 " chlorohydric acid	= sal-ammoniac.
100 " do.	+ 100 " carbonic acid	= carbonate of ammonia.
100 " do.	+ 200 " do.	= bicarbonate of ammonia.
600 " hydrogen	+ 100 " vapor of sulphur	= sulphuretted hydrogen.
600 " oxygen	+ 100 " do.	= sulphurous acid.
100 " hydrogen	+ 100 " vapor of iodine	= iodohydric acid.

The volumes of compound gases and vapors always bear a very simple ratio to the volumes of their elements. This will appear from the

following table, in which all the substances are supposed to be in the gaseous state:—

Volumes of Elements.		Volumes of resulting compounds.	
100 Nitrogen	+ 300 Hydrogen	yield 200 Ammonia.	
50 Oxygen	+ 100 Hydrogen	 100 Water.	
50 Oxygen	+ 100 Nitrogen	 100 Nitrous oxide.	
100 Sulphur	+ 600 Hydrogen	 600 Hydrosulphuric acid.	
100 Sulphur	+ 600 Oxygen	 600 Sulphurous acid.	
100 Chlorine	+ 100 Hydrogen	 200 Chlorohydric acid.	
100 Iodine	+ 100 Hydrogen	 200 Iodohydric acid.	
100 Bromine	+ 100 Hydrogen	 200 Bromohydric acid.	
100 Cyanogen	+ 100 Hydrogen	 200 Cyanohydric acid.	
100 Oxygen	+ 100 Nitrogen	 200 Nitric oxide.	

The law of multiples (see above) is equally demonstrable by means of combining or eq. volumes as by combining or eq. weights. The

annexed tabular view will justify this statement:—

Volumes of Elements.		Resulting Compounds.	
100 Nitrogen	+ 50 Oxygen	yield Nitrous oxide.	
100 do.	+ 100 do.	 Nitroic oxide.	
100 do.	+ 150 do.	 Hyponitrous acid.	
100 do.	+ 200 do.	 Nitrous acid.	
100 do.	+ 250 do.	 Nitric acid.	
100 Hydrogen	+ 50 do.	 Water.	
100 do.	+ 100 do.	 Binoxide of hydrogen.	
100 Carbon vapor	+ 50 do.	 Carbonic oxide.	
100 do.	+ 100 do.	 Carbonic acid. (<i>Turner.</i>)	

See farther under ATOMIC THEORY, COMBINING WEIGHTS connection between combining

and specific weights, ATOMIC VOLUME, and VOLUME.

The following, drawn from Graham, presents an excellent view of the relation between combining weights and gaseous volumes. See also Gmelin's *Chemie*, 4th edition, 1843, vol. i., pp. 54, 66, &c.

The uniformity of properties observed among gases in compressibility and dilatibility by heat has appeared to many chemists to indicate a similarity of constitution, and to favor the idea that they all contain the same number of atoms in the same volume. May not equal volumes of oxygen and hydrogen gases, for instance, be represented by an equal number of atoms of oxygen and hydrogen respectively placed at equal distances from each other, and the difference from 16 to 1 in the densities of the two gases arise from the atom of oxygen being really 16 times heavier than that of hydrogen? Equal volumes of gases would then contain an equal number of atoms, and 1, 2, or 3 volumes would be an equivalent expression to 1, 2, or 3 atomic proportions, the terms *volume* and *atom* becoming of the same import, or expressing equal quantities of bodies. But such a view is obviously inapplicable to compound gases, as their volume has a variable relation to that of their elements; and its adoption would require grave alterations to be made in the combining weights of several of the elements themselves, to accommodate these weights to the observed densities of the bodies in the gaseous state. This will be seen from the following table, in which the volume or fractional part of a volume placed against each element always contains the same number of its presently received atoms. These volumes are, therefore, the equivalent volumes of the elements, and may be viewed as representing the bulk of their atoms in the gaseous state, *the combining volume of hydrogen being here taken as one.*

	Atoms.	
	Volume.	Weight.
Hydrogen	1	1
Nitrogen	1	14.2
Chlorine	1	35.5
Bromine	1	78.39
Iodine	1	126.57
Oxygen	$\frac{1}{2}$	8
Phosphorus	$\frac{1}{2}$	31.44
Arsenic	$\frac{1}{2}$	75.34
Sulphur	$\frac{1}{8}$	16.12
Mercury	2	101.43

Of the first five bodies enumerated, equivalent weights occupy equal volumes. It was indeed the observation of this equality between the atom and volume in these gases, that led to the supposition of that relation being general. But the atoms of oxygen, phosphorus, and arsenic occupy only half a volume, and would require to be doubled to fill the same volume as the preceding class. The present atom of sulphur affords only one-sixth of a volume of vapor, and must, therefore, be multiplied by six to afford a whole volume; while the atom of mercury supplies two volumes of vapor, and would, therefore, require to be divided by two, or reduced to one-half of its present number. Gmelin terms sulphur a

hexatomic gas; oxygen, phosphorus, and arsenic, diatomic; and the others of the above table monatomic. Of these changes the required modification of the atoms of phosphorus, arsenic, and sulphur is incompatible with their chemical relations to other bodies which are best established, and is quite inadmissible. The densities of the vapors of these bodies must, therefore, be viewed as decisive against the equality of the equivalent volumes of the elementary gases. A volume of sulphur vapor must be allowed to contain three times as many atoms as an equal volume of oxygen gas, six times more than the same volume of hydrogen gas, and 12 times more than the same volume of mercury vapor. A similar constitution cannot be assigned to these vapors, unless on the assumption of Dumas, that chemical atoms of the same kind may group together, and form larger compound atoms or molecules, or divide into smaller molecules. The molecule of hydrogen in the gaseous state being the same as its chemical atom, each molecule of oxygen while in the state of gas would be an aggregate of two chemical atoms, and each of sulphur of six; while mercury must suffer molecular division in the state of vapor, each of its chemical atoms being parted into two, in order that equal volumes of these different gases and vapors should contain the same number of molecules or atoms. But such views are entirely speculative.

In the farther consideration of the proportions in which gases combine by measure, it will be found conducive to perspicuity to adopt the combining volume of oxygen as the unit (instead of that of hydrogen as in the last table), in terms of which to express the combining measures of other gases, both simple and compound. The combining measure of oxygen being one volume, *the combining measure* of hydrogen and its class will be *two volumes*; or the atom of oxygen gives one, and the atom of hydrogen two volumes of gas. Volumes of the gases may be represented by equal squares with their relative weights inscribed, the numbers having reference to the number assigned to the oxygen volume. If that number be 8, or the atomic weight of oxygen, as in column I of the table below, then the number to be inscribed in each of the two volumes forming the combining measure of hydrogen will be $\frac{1}{2}$ or half its atomic weight, the combining measure itself having the full atomic weight of hydrogen, namely 1; and so of other gases, the combining measure has the whole atomic weight which is divided among the component volumes. But there is reason for preferring the number 1102.6 to 8 for the standard oxygen volume, that the weight of a volume of *air* being taken as 1000, that of an equal volume of oxygen is 1102.6; and consequently the corresponding number for the volume of hydrogen, 69, expresses the relation in weight of that gas also to air, and so do the corresponding numbers for all the other gases. The numbers on this scale, which express the relative densities of a volume of each gas, and are inscribed in the squares of column II., are indeed the common *specific gravities of the gases.*

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I.		II.	
Atomic weight		Combining measure.	Combining measure.
			Air.. 1000
Oxygen.....	8	8	 1102·6
Phosphorus	31·44	31·44	 4327
Hydrogen.....	1	$\frac{1}{2}$	 69
		$\frac{1}{2}$	 69
Chlorine.....	35·5	17·75	 2470
		17·75	 2470
Mercury	101·43	25·36	 6969
		25·36	 6969

The double squares which represent the combining measures of hydrogen and chlorine are divided into volumes by *dotted* lines, to show that the division is imaginary, the partition of a combining measure, like that of an atom which it represents, being impossible. The specific gravities of gases being merely the relative weights of equal volumes, may be expressed by the numbers in the squares of the first column; and the specific gravity of oxygen being accordingly made 8, the specific gravity of any other gas will either be the same number as its atomic weight or an aliquot part of it.

The combining measures of compound gases, although variable, have still a constant and a simple relation to each other, such as 1 to 1, 1 to 2, or 2 to 3; their elements in combining, suffering either no condensation, or a definite and very simple change of volume. Hence

the density of a compound gas may often be calculated with more precision, from the densities of its constituents, and a knowledge of the change of volume, if any, which occurred in combination, than it can be determined by experiment.

To deduce on this principle the specific gravity of steam. It consists of single equivalents of oxygen and hydrogen, of which the combining measure of the first is 1, and that of the second 2 volumes. These *three* volumes weigh $1102·6 + 69 + 69 = 1240·6$, and they form *two* volumes of steam; of which one volume must, therefore, weigh $1240·6$ divided by 2, or 620·3, which is, consequently, the calculated specific gravity of steam referred to that of air, as 1000. The relations in volume of the gases before and after combination may be thus exhibited:

Combining measure, or one volume of oxygen		Combining measure or two volumes of hydrogen.		Combining measure or two volumes of steam.
1102·6	· + ·	69	· = ·	620·3
		69		620·3
1240·6				1240·6

It thus appears necessary to inscribe 620·3 in each volume of steam, to make up 1240·6, the known weight of the 2 volumes.

In the formation of the hydrochloric acid,

equal measures of chlorine and hydrogen unite without condensation, so that the product possesses the united volumes of its constituent gases.

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Combining measure of hydrogen,
or two volumes.

69
.....
69

+

Combining measure of chlorine,
or two volumes.

2470
.....
2470

=

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Combining measure of hydro-
chloric acid, or four volumes.

1269.5	1269.5
.....	
1269.5	1269.5

5078

5078

The specific gravity or weight of a single volume of hydrochloric acid is therefore obtained by dividing 5078 by 4, and is 1269.5.

The specific gravity of the vapor of an elementary body, which there are no means of ascertaining experimentally, may sometimes be calculated from the known density of a gaseous compound containing it. The density of carbon vapor may be thus deduced from the observed density of carbonic oxide gas. Assuming that the combining measure of carbon is double that of oxygen, as is true of hydrogen

and several other elementary bodies, then carbonic oxide, which, like water, consists of single equivalents of its constituents, will resemble steam in its constitution also, and be composed of 1 volume of oxygen gas and 2 volumes of carbon vapor condensed into 2 volumes. The weight of a single volume of carbonic oxide being 972.7, 2 volumes (1945.4) may be resolved, as shown in the diagram below, into 1 volume of oxygen, 1102.6, and 2 volumes of carbon vapor, 842.6, (1945.4—1102.6 = 842.6) each of which it follows, must weigh 421.3.

Combining measure, or two volumes of carbonic oxide.

972.7
.....
972.7

=

Combining measure, or one volume of oxygen.

1102.6
.....
1102.6

+

Combining measure, or two volumes of carbon vapor.

421.3
.....
421.3

1945.4

1945.4

But the density 421.3 thus assigned to carbon vapor, will only be true if it corresponds with hydrogen in its combining measure; but the combining measure of carbon vapor may as well be one-half that of hydrogen, like that of phosphorus, or one-sixth like that of sulphur, and then the density will be double, or six times that supposed. The important conclusion, however, that the density of carbon vapor is either 421.3, or some multiple or sub-multiple of that number is quite certain.

The two following tables comprise nearly all the accurate information which chemists at present possess respecting the specific gravities of gaseous bodies. The bodies placed in the first table are generally considered as belonging to the inorganic, and those in the second to the organic department of the science.

From these tables, it appears that a simple relation always subsists between the combining measures of different bodies in the gaseous state:

That the combining measure of a few bodies is the same as that of oxygen, or *one volume*; of a large number, double that of oxygen, or *two volumes*; and of a still larger number, four times that of oxygen, or *four volumes*; while combining measures of other numbers of volumes, such as *three* and *six*, or of fractional portions of one volume, such as *one-third*, are comparatively rare;

That the specific gravity of a gas may be calculated from its atomic weight, or the atomic weight from the specific gravity, as they are necessarily related to each other. Thus, to find the

specific gravity of a vapor like that of phosphorus, of which the combining measure is one volume, or the same as that of oxygen. The specific gravities of two bodies, of which the *volumes* of the atoms are the same, must obviously be as the *weights* of these atoms. Hence, 8 and 31.43 being the atomic weights of oxygen and phosphorus, and 1102.6, the known spec. grav. of oxygen, the spec. grav. of phosphorus vapor is obtained by the following proportion—

$$8.01 : 31.43 :: 1102.6 : 4325.3$$

= spec. grav. of phosphorus vapor.

Secondly, to find the specific gravity of a vapor like that of fluorine, of which the combining measure may be presumed to be two, or double that of oxygen. The atomic weight of fluorine being 18.74,

$$8.01 : 18.74 :: 1102.6 : 2577.9$$

twice the spec. grav. of fluorine, being the weight of two volumes, and the spec. grav. required is 1288.9.

These cases are examples of a general rule, that the specific gravity of a body in the state of vapor is obtained by multiplying the atomic weight of the body by 1102.6, the specific gravity of oxygen, and dividing by 8.01. The number thus found must then be divided by the number of volumes which are known to compose the combining measure of the vapor.

The specific gravities thus calculated are generally more accurate than those obtained by direct experiment, from the circumstance that the operation of taking the specific gravity of a gas is generally less susceptible of pre-

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cision, than the chemical analyses on which the atomic weights are founded. The densities of vapors, taken a few degrees above their condensing points, are generally a little greater than the truth, owing to a peculiarity in their physical constitution. See VAPORS. Of such bodies, therefore, the theoretical is a necessary check upon the experimental density. Indeed, the calculated should in all cases be considered and used as the true density.

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See also full tables in Gmelin's *Chemie*, vol. i. pp. 66, 70, &c.

From the uniform combination of bodies by equivalents, formulæ have been devised to express compounds concisely by employing letters as symbols of the elements and of some compounds; see FORMULA. For the mode of calculating the combining weights of bodies and their uses in analysis, &c., see COMBINING WEIGHTS and ANALYSIS, and for the combining weights of bodies see the Table of EQUIVALENTS.

TABLE I.

Gases and Vapors.	Density.	Atom.	
	Air = 1000.	Volumes in combining measure.	Weight.
Oxygen.....	1102.6	1	8.01
Phosphorus.....	4327	1	31.43
Arsenic.....	10362	1	75.34
Arsenious acid.....	13670	1	99.34
Sulphuret of mercury.....	5384	$\frac{2}{3}$	117.55
Sulphur.....	6648	$\frac{1}{8}$	16.12
Hydrogen.....	69	2	1
Nitrogen.....	976	2	14.19
Carbon (hypothetical).....	421.5	2	6
Chlorine.....	2470	2	35.5
Iodine.....	8701	2	126.57
Bromine.....	5393	2	78.39
Water.....	620.2	2	9
Nitrous oxide.....	1527.3	2	22.19
Carbonic oxide.....	972.8	2	14
Carbonic acid.....	1524.1	2	22
Sulphurous acid.....	2210.6	2	32.12
Sulphuric acid (anhydrous).....	2761.9	2	40.12
Sulphuretted hydrogen.....	1177	2	17.12
Light carburetted hydrogen.....	595.5	2	8
Cyanogen.....	1819	2	26.19
Mercury.....	6969	4	101.43
Nitric oxide.....	1039.3	4	30.19
Hydrochloric acid.....	1269.5	4	36.5
Hydriodic acid.....	4385	4	127.57
Hydrobromic acid.....	2731	4	79.39
Hydrocyanic acid.....	944	4	27.19
Ammonia.....	591.5	4	17.19
Arsenuretted hydrogen.....	2695	4	78.34
Terchloride of arsenic.....	6295	4	181.84
Teriodide of arsenic.....	15640	4	455.05
Subchloride of mercury.....	8204	4	238.36
Chloride of mercury.....	9439	4	136.93
Subbromide of mercury.....	9665	4	281.25
Bromide of mercury.....	12362	4	179.82
Iodide of mercury (red).....	15670	4	228

TABLE II.

Gases and Vapors.	Formula.	Density.		Volumes in combining measure.	Observer.
		Air = 1000.			
		Calculated	Observed.		
Ether.....	C_4H_5O	2583	2586	2	Gay-Lussac.
Methylic ether.....	C_2H_5O	1601	1617	2	Dumas and Peligot.
Sulphate of methylene.....	C_2H_3O, SO_3	4369	4565	2	Do.
Oxalic ether.....	C_2H_3O, C_2O_3	5081	5087	2	Dumas and Boullay.
Succinic ether.....	$C_4H_5O, C_4H_3O_3$	6201	6220	2	Felix d'Arcet.
Oenanthic ether.....	$C_4H_5O, C_{14}H_{13}O_2$	10477	10508	2	Liebig and Pelouze.
Alkarsine.	C_4H_6As	7281	7184	2	Bunsen.
Acetic acid.....	$C_2H_4O_2$	2778	2770	3	Dumas.
Methylene.....	C_2H_2	490	.	4	Dumas and Peligot.
Olefiant gas.....	C_2H_4	981	985	4	M. de Saussure.
Gas from oil.....	C_8H_8	1962	1892	4	Faraday.
Oleene.....	$C_{12}H_{12}$	2942	2875	4	Fremy.
Elaene.....	$C_{18}H_{18}$	4156	4071	4	Do.
Cetene.....	$C_{32}H_{32}$	7846	8007	4	Dumas and Peligot.
Benzin.....	$C_{12}H_6$	2736	2770	4	Mitscherlich.
Retinaphtha.....	$C_{14}H_8$	3226	3230	4	Pelletier and Walter.
Retinyle.....	$C_{18}H_{12}$	4247	4242	4	Do.
Retinole.....	$C_{32}H_{16}$	7290	7110	4	Do.
Naphthaline.....	$C_{20}H_8$	4488	4528	4	Dumas.
Paranaphthaline.....	$C_{30}H_{12}$	6732	6741	4	Dumas and Laurent.
Camphene or oil of turpentine.	$C_{20}H_{16}$	4763	4765	4	Dumas.
Camphor.....	$C_{20}H_{16}O_2$	5314	5468	4	Do.
Menthene (from oil of mint)...	$C_{20}H_{18}$	4830	4940	4	Walter.
Concrete essence of mint....	$C_{20}H_{20}O_2$	5450	5620	4	Do.
Wood-spirit.....	$C_2H_4O_2$	1110	1120	4	Dumas and Peligot.
Hydrochlorate of methylene..	C_2H_3Cl	1738	1731	4	Do.
Hydrofluatate of methylene....	C_2H_3F	1169	1186	4	Do.
Hydriodate of methylene.....	C_2H_3I	4882	4883	4	Do.
Nitrate of mythylene.....	C_2H_3O, NO_5	2640	2653	4	Do.
Formate of methylene.....	C_2H_3O, C_2HO_3	2083	2084	4	Do.
Acetate of methylene.....	$C_2H_3O, C_4H_3O_3$	2573	2563	4	Do.
Alcohol.....	$C_2H_6O_2$	1601	1613	4	Gay-Lussac.
Mercaptan.....	$C_2H_6S_2$	2158	2326	4	Bunsen.
Hydrochloric ether.....	C_4H_5Cl	2229	2219	4	Thénard.
Hydriodic ether.....	C_4H_5I	5321	5475	4	Gay-Lussac.
Nitrous ether.....	C_4H_5O, NO_3	2606	2626	4	Dumas and Boullay.
Chlorocarbonic ether.....	C_4H_5O, C_2O_3Cl	3759	3829	4	Dumas.
Acetic ether.....	$C_4H_5O, C_4H_3O_3$	3066	3067	4	Do.
Benzoic ether.....	$C_4H_5O, C_{14}H_3O_3$	5240	5409	4	Do.
Pyromucic ether.....	$C_4H_5O, C_{10}H_3O_5$	4878	4859	4	Malaguti.
Chloride of aldehydene.....	C_4H_3Cl	2166	.	4	Liebig and Pelouze.
Oil of olefiant gas.....	C_4H_3Cl, HCl	3407	3443	4	Gay-Lussac & Dumas.
Bromide of aldehydene.....	C_4H_3Br	3642	3691	4	Regnault.
Hydrocarburet of bromine....	C_4H_3Br, HBr	6373	6485	4	Do.
Chloral.....	$C_2HCl_2O_2$	5060	5130	4	Dumas.
Choloroform.....	C_1HCl_3	4113	4199	4	Do.
Urethane.....	$C_6NH_7O_4$	3140	3096	4	Do.
Oil of the ardent spirits from potatoes.....	$C_{10}H_{12}O_2$	3072	3147	4	Do.
Aldehyde.....	$C_4H_4O_2$	1531	1532	4	Liebig.
Acetone.....	$C_6H_6O_2$	2020	2019	4	Dumas.
Benzoic acid.....	$C_{14}H_6O_4$	4260	4270	4	Dumas & Mitscherlich.
Eugenic acid.....	$C_{20}H_{12}O_5$	6000	6400	4	Dumas.
Formethylal.....	$C_8H_{10}O_6$	2456	2500	6	Dumas.

III. CHANGES RESULTING FROM THE COMBINATION OF SUBSTANCES.

The definition of chemical affinity given above requires a change in the character of a resulting compound, which shall distinguish it in all its essential qualities from its constituents. In many cases all the properties are altered, in others the more important only; if

solution be embraced under affinity, then the change is only one of state or cohesion; salt dissolved in water has merely passed into the liquid state, retaining otherwise its properties. The changes are referrible to density, state, form, different relations to light and heat, different chemical and physiological effects, &c.

1. *Change of Density.* (See also above Com-

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bination by volume). There is generally a change of volume with aeriform substances, usually expansion, very rarely a diminution; in some cases no change. The following table from Gmelin exhibits this in a clearer light.

Column A. Name of the compound.

" B. Formula.

" C. N° of measures of the combining substances.

" D. The sum of these measures of C. before combination.

" E. " " after " "

" F. Combining weight.

" G. Specific weight, compared with air = 1.

" H. Atomic number, = spec. grav. divided by comb. weight.

A.	B. Formula.	C. Measures.	D.	E.	F. C. W. H = 1.	G. Sp. Gr. Air = 1.	H. Atomic No.
Chlorohydric acid	H Cl	1H,1Cl	2	2	36·5	1261·8	34·6
Nitric oxide	NO ₂	1N,1O	2	2	30·2	1039·9	34·6
Chlorohydr. ammonia	NH ₃ ,HCl	1NH ₃ ,1HCl	2	2	53·4	890	16·7
Bihydrosulphur. ammon...	NH ₃ ,2HS	1NH ₃ ,1HS	2	2	51	884	17·3
Carb. ammonia (neutral) ..	NH ₃ ,CO ₂	2NH ₃ ,1CO ₂	3	3	39	900	23·1
Sulphurous acid	SO ₂	1S,6O	7	6	32	2218·6	69·3
Sulphohydric acid	HS	1S,6H	7	6	17	1178·6	69·3
Bisulphuret of carbon	CS ₂	3!C,1S	4	3	38	2634·5	69·3
Terchloride of arsenic	As Cl ₃	1As,6Cl	7	4	181·4	6300·6	34·7
Water	HO	2H,1O	3	2	9	623·9	69·3
Nitrous oxide	NO	2N,1O	3	2	22	1525·2	69·3
Sulphuric acid.....	SO ₃	1S,9O	10	6	40	3000	75
Nitric acid.....	NO ₅	2N,5O	7	2	54	13742·2	69·3
Arsenious acid.....	AsO ₃	1As,3O	4	1	99·2	13850·0	139·6
Sulphuret of mercury	HgS	6Hg,1S	7	9	117·4	5510·	46·9

There is always a change of volume by combination of solids or liquids, and generally a condensation. Expansion is very rare, and is feebly shown by the combination of iodine with potassium, lead, mercury, or silver; sulphur with arsenic (realgar), copper (subsulphuret) or cadmium, &c. (Full tables are contained in Gmelin's *Chemie*, vol. i. p. 70—74.)

2. *Change of State.* The change of bodies into a different state by combination is exceedingly various. A solid may arise from the union of two gases, carbonic acid and ammonia; of a gas and liquid, mercury and chlorine; of a gas and solid, potassium, iron, &c., and oxygen; of two liquids, mercury and bromine; of a liquid and solid, water and lime, or sulphur and mercury; of two solids, sulphur and copper in the cold, or generally by fusion, sulphur and a metal. A liquid may be formed of two gases, oxygen and hydrogen; of a gas and liquid, chlorine and bromine; of a gas and solid, chlorine and antimony; of two solids, or a liquid and solid, at high temperature, carbon and sulphur. A gas is formed from two gases, hydrogen and chlorine; from a gas and liquid, hydrogen and bromine; from a gas and solid, hydrogen and sulphur, oxygen and carbon.

3. *Change of Form.* It is probable that the form of a crystal bears a certain relation to its constituents, but this relation has not been fully determined. Sulphur and silver of two different crystalline forms unite and form a compound agreeing with neither constituent. See farther on the subject of form under CRYSTALLOGRAPHY, ISOMORPHISM, DI- and TRIMORPHISM, ISOMERISM.

4. *Relation to Light.* Two transparent bodies

always form a transparent compound, oxygen and hydrogen; two opaque an opaque compound, arsenic and iron; 1 transparent and 1 opaque form sometimes a transparent, oxygen and potassium, sulphur and zinc; sometimes an opaque body, oxygen and manganese, sulphur and iron.

Colorless bodies often produce colorless compounds, silica with the alkalies and earths, oxygen and hydrogen; often colored, as many vegetable substances, hyponitric acid: colored bodies produce colorless, chlorine and alkaline metals; or colored, sulphur and copper or iron, chlorine and copper. There appears to be no uniform relation between the color of a body and its constituents, although a few may be classed together with exceptions, thus the chromates are usually reddish or yellowish, the salts of suboxide of copper usually reddish, those of the oxide blue or green, &c. Observation of color is nevertheless very important, as it often enables us to distinguish bodies even in mixtures.

Gaseous bodies refract light sometimes more, sometimes less than the mean calculated refraction of their constituents; thus chlorohydric acid gas has an observed refraction of 1·527 (air=1); whereas, by calculation, it should be 1·547; and nitric oxide by observation is 1·03, by calculation 0·972. Some bodies in passing from a gaseous to a liquid state, increase in refractive power greater than in density. Light is often evolved by the union of bodies, combustion in air and oxygen, antimony in chlorine, sulphur and iron, &c.

5. *Relation to Heat.* Compounds are generally more fusible, the metallic never less, than their

constituents (see *Alloy* and *Solder*); some sulphurets are more infusible, sulphuret of zinc. The volatility of a compound is generally lower than that of its constituents; phosphuret of nitrogen withstands a white heat; volatility is often a medium, the more volatile imparting its character to the other, iron and chlorine; a compound is rarely more volatile than each of its constituents, bisulphuret of carbon.

There is an evolution of heat by the chemical union of bodies, water, and quick-lime, combustion in general. This subject has received much attention of late. See *COMBINATION, COMBINING WEIGHTS*.

6. *Chemical and Physiological Effects*. Compounds generally exhibit very different affinities and different effects in the animal economy from their constituents; nitrogen, which is very indifferent, forms with oxygen the corrosive nitric acid; with hydrogen the caustic alkali ammonia, and with carbon and hydrogen, the highly poisonous prussic acid. By the union of nitric acid and ammonia, neither the acid nor alkaline properties are detected, and the one is said to be neutralized by the other. See *NEUTRALIZATION and SALT*.

For a few other peculiar effects of affinity, on the character of a substance, see the several articles *AMORPHISM, POLYMERISM, METAMERISM*, beside those referred to above.

IV. DECOMPOSITION.

The preceding sections refer chiefly to compounds which have been formed, and the alterations they have consequently suffered; the laws governing their union, by weight and by measure. We may now regard the conditions and circumstances of their decomposition; the destruction or alteration of existing affinities, or affinity in a more active state. The same laws and conditions hold good of decomposi-

tion as well as of combination; and in fact the greater number of decompositions are due to the exertion of new or superior affinities, modified, however, by circumstances. Although bodies may be made to unite by *pressure, heat, &c.*, yet by withdrawing or diminishing these, we cannot again separate them. Neither *Gravity, Cohesion*, nor *Adhesion*, will separate the constituents of a chemical compound. *Contact* or *catalysis* appears to effect decomposition as well as union. Affinity, by induction, or *imparted affinity* has considerable influence in exciting action where it did not previously exist, or was at least very feeble, producing decompositions which would not otherwise take place; thus, while binoxide of hydrogen, in contact with oxide of silver, loses its oxygen, it causes, at the same time, the silver to lose its oxygen; and possibly for the same reason, in the vinous fermentation, the ferment in the act of decomposition, induces a similar change in the sugar, by which it separates into carbonic acid and alcohol. (See above, *Inducing Affinity*, as a condition of chemical union.) Decomposition within plants and animals, ascribed to vitality, is probably due to the conjoint action of life and ponderable matter or imponderables; thus the decomp. of carbonic acid by the action of light in the green part of plants, which then assimilate carbon in manifold ways. Preponderating affinities are most active and important in chemical changes, and have been divided into several kinds.

1. *Single Elective Affinity*. It was observed as early as the close of the 17th century, that a different degree of affinity existed between bodies; and Geoffroy, in 1718, projected tables exhibiting the order of affinity, which were subsequently modified and improved by Bergman and others. The following tables of single elective affinity illustrate this:

1. Sulphuric acid.	2. Muriatic acid.	3. Soda.	4. Oxygen.
Baryta	Oxide of silver	Sulphuric acid	Zinc
Strontia	Potassa	Nitric "	Nickel
Potassa	Soda	Muriatic "	Lead
Soda	Baryta	Oxalic "	Copper
Lime	Strontia	Acetic "	Mercury
Magnesia	Lime	Carbonic "	Silver
Oxide of silver	Magnesia		

The substance at the head of each column is supposed to have the strongest affinity for the substance next below it, and a weaker for each one successively beneath it.

Such tables are now, however, abandoned, since other circumstances influence the order of decomposition (see below), as is evident from tables 1 and 2; where the order is different in reference to two different acids, is nearly reversed, the sulphuric having apparently the feeblest attraction for oxide of silver, while the muriatic has the strongest affinity for the same base.

In single elective affinity a compound AB is decomposed by C, a new body AC being formed while B is set free. Examp. Oxides of zinc, iron, copper, &c., decomposed by carbon into carbonic acid or oxide and the metal set free; chlorine expels oxygen from ignited potassa, forming chloride of potassium and evolving

oxygen; sulphuret of lead and iron ignited form sulphuret of iron, and lead is set free; acetic acid sets carbonic acid free from carbonate of lime, while from the residuary acetate of lime sulphuric expels the acetic; potassa precipitates oxide of iron from the sulphate of iron, while sulphate of potassa remains in solution. The presence of a 4th body, D, is often requisite, which will unite with the new body AC; thus water (AB), with sulphuric acid (D) is decomposed by zinc (C), forming sulphate of oxide of zinc (AC + D) and liberating hydrogen (B). Copper precipitates silver from the nitrate of the oxide in solution; lead precipitates copper, and zinc again precipitates lead. Sometimes C removes from AB only a part of A; thus ignited zinc removes only a part of oxygen from carbonic acid, forming oxide of zinc and carbonic oxide.

The compound AB decomposes with C into

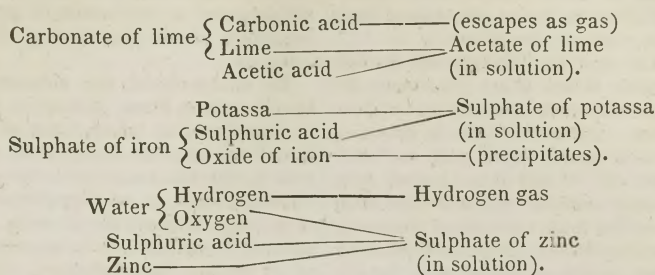
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2 new compounds AC and BC. Sulphuret of zinc and other metallic sulphurets calcined in the air, yield sulphurous acid and oxide of zinc; many sulphurets heated in chlorine form chlorides of sulphur and of the metal; the 2 new compounds may sometimes unite; thus

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galena (sulphuret of lead) calcined in the air, forms much sulphate of oxide of lead. The presence of a 4th body, D, varies the resulting compounds, as above.

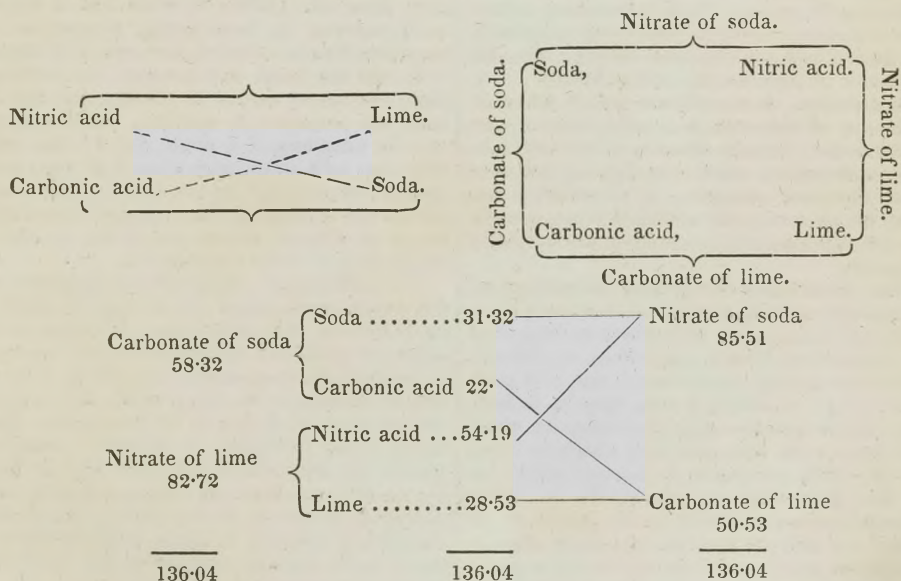
The following diagrams illustrate decomposition by single elective affinity:



(See DIAGRAMS.)

2. *Double Elective Affinity.* When 4 bodies are present instead of 3, a double interchange of constituents takes place. AB and CD form AC and BD. Thus, pentachloride of phosphorus PCl_5 decomposes with water $5\text{H}_2\text{O}$ into chlorohydric 5HCl and phosphoric acids PO_5 . Sulphuretted hydrogen passed through some metallic oxides, forms a sulphuret of the metal and water. But such decompositions are usu-

ally observed between salts, their acid and metallic oxide being the proximate constituents. Such decompositions are represented in the following diagrams, between nitrate of lime and carbonate of soda, whose mingled solutions form an insoluble precipitate of carbonate of lime, while nitrate of soda remains in solution.



(See DIAGRAMS.)

Although theoretically speaking, double elective affinity is but an extension of single elective, yet it is of the highest importance in chemical changes, many compounds being capable of formation solely by its action, particularly where one is soluble and the other an insoluble precipitate. In the above example the carbonic acid has an attraction both for soda and lime, and the nitric also for the same bases; but it appears that the affinities of carbonic acid for lime, and the nitric for soda, preponderate over those of the carbonic for soda, and nitric for lime. The preponderating are sometimes termed *divellent*, and the minor *quiescent*, affinities.

Double decomposition was long since noticed, and Richter established his law of neutrality upon it; which is, that when 2 neutral salts mutually decompose each other, the two resulting salts are also neutral (see *NEUTRALIZATION*). From the different weights of the substances employed and their resulting compounds, it was regarded as a very remarkable fact; but it flows necessarily from the laws of combination (see these), in which it is shown that bodies combine according to fixed numbers for each body, but very different numbers for different bodies. Now, when 2 neutral salts, consisting each of an equiv. of acid and base, mutually and fully decompose each other (as

the nitrate of lime and carbonate of soda, in the above diagram), the equiv. of carbonic acid = 22, unites precisely with an eq. of lime = 28.53; and the eq. of nitric 54.19, with the eq. of soda = 31.32; but their several weights will be very different; for the 53.32 of carb. soda, and the 82.72 nitrate of lime, become 85.51 nitrate of soda, and 50.53 carb. lime; the sum of their several weights remains the same.

The body AB may be decomposed by CD, forming AC, while B and D are separately uncombined; thus carbonate of soda and sulphate of alumina form sulphate of soda in solution, while alumina is precipitated, and carbonic acid gas passes off; C and D not united may act upon AB; thus metallic oxides heated with chlorine and carbon form chloride of the metal and carbonic oxide or acid. A 5th body, E, may produce similar results as noticed with the 4th body under single elective affinity.

ABC and DEF may form 3 compounds AD, BE, CF; thus sulphohydrate of ammonia with nitrate of lead produces sulphuret of lead, nitrate of ammonia, and water.

V. CIRCUMSTANCES WHICH MODIFY ELECTIVE AFFINITY.

Although the laws of combination cannot be altered, yet circumstances may apparently and really change the order of elective affinity, or influence its action. Such influencing causes are cohesion, elasticity, temperature, quantity of matter, and predisposing affinity. For the influence of light see the article LIGHT.

1. *Cohesion.* It was shown before that a diminution of cohesion in a solid, favored chemical action (see the 1st part of Affinity); cohesion, therefore, exerts a modifying influence over chemical changes. It is probable that heat, by opposing the cohesive force, usually assists combination, particularly when applied to solids.

The insolubility (or greater coherence) of a possible resulting compound is of the highest importance, and often determines its formation in apparently direct opposition to affinity. "Thus, on mixing together a solution of 2 acids and 1 alkali, of which 2 salts may be formed, one soluble and the other insoluble, the alkali will unite with that acid with which it forms the insoluble compound, to the total exclusion of the other. This is one of the modifying circumstances employed by Berthollet to account for the phenomena of single elective attraction, and is certainly applicable to many of the instances to be found in the tables of affinity. When, for example, hydrochloric acid, sulphuric acid, and baryta are mixed together, sulphate of baryta is formed in consequence of its insolubility. Lime, which yields an insoluble salt with carbonic acid, separates that acid from ammonia, potassa, and soda, with all of which it makes soluble compounds.

A similar explanation may be given of many cases of double elective attraction. On mixing together in solution 4 substances, A, B, C, D, of which it is possible to form 4 compounds, AB and CD, or AC and BD, that compound will generally be produced which happens to be insoluble. Thus, sulphuric acid, soda, nitric acid, and baryta may give rise either to sulphate of

soda and nitrate of baryta, or to sulphate of baryta and nitrate of soda; but the first 2 salts cannot exist together in the same liquid, because the insoluble sulphate of baryta is instantly generated, and its formation necessarily causes the nitric acid to combine with the soda. In like manner, a solution of nitrate of lime is decomposed by carbonate of ammonia, in consequence of the insolubility of carbonate of lime.

To comprehend the manner in which cohesion acts in these instances, it is necessary to consider what takes place when in the same liquid two or more compounds are brought together, which do not give rise to an insoluble substance. Thus, on mixing solutions of sulphate of potassa and nitrate of soda, no precipitate ensues; because the salts capable of being formed by double decomposition, sulphate of soda and nitrate of potassa, are likewise soluble. In this case it is possible either that each acid may be confined to one base, so as to constitute 2 neutral salts; or that each acid may be divided between both bases, yielding 4 neutral salts. It is difficult to decide this point in an unequivocal manner: but, judging from many chemical phenomena, there can, I apprehend, be no doubt that the arrangement last mentioned is the most frequent, and is probably universal whenever the relative forces of affinity are not very unequal. When 2 acids and 2 bases meet together in neutralizing proportion, it may therefore be inferred, that each acid unites with both the bases in a manner regulated by their respective forces of affinity, and that 4 salts are contained in solution. In like manner, the presence of 3 acids and 3 bases will give rise to 9 salts; and when 4 of each are present, 16 salts will be produced. This view affords the most plausible theory of the constitution of mineral waters, and of the products which they yield by evaporation.

The influence of insolubility in determining the result of chemical action may be readily explained on this principle. If nitric acid, sulphuric acid, and baryta are mixed together in solution, the base may be conceived to be at first divided between the 2 acids, and nitrate and sulphate of baryta to be generated. The latter, being insoluble, is instantly removed beyond the influence of the nitric acid, so that for an instant nitrate of baryta and free sulphuric acid remain in the liquid: but as the base left in solution is again divided between the 2 acids, a fresh quantity of the insoluble sulphate is generated; and this process of partition continues, until either the baryta or the sulphuric acid is withdrawn from the solution. Similar changes ensue when nitrate of baryta and sulphate of soda are mixed.

The separation of salts by crystallisation from mineral waters or other saline mixtures is explicable by a similar mode of reasoning. Thus, on mixing nitrate of potassa and sulphate of soda, 4 salts, according to this view, are generated,—namely, the sulphates of soda and potassa, and the nitrates of those bases; and if the solution be allowed to evaporate gradually, a point at length arrives when the least soluble of these salts, the sulphate of potassa, will be disposed to crystallise. As

soon as some of its crystals are deposited, and thus withdrawn from the influence of the other salts, the constituents of these undergo a new arrangement, whereby an additional quantity of sulphate of potassa is generated; and this process continues until the greater part of the sulphuric acid and potassa has combined, and the compound is removed by crystallisation. If the difference in solubility is considerable, the separation of salts may be often rendered very complete by this method.

The efflorescence of a salt is sometimes attended with a similar result. If carbonate of soda and chloride of calcium are mingled together in solution, the insoluble carbonate of lime subsides. But if carbonate of lime and sea-salt are mixed in the solid state, and a certain degree of moisture is present, carbonate of soda and chloride of calcium are slowly generated; and since the former, as soon as it is formed, separates itself from the mixture by efflorescence, its production continues progressively. The efflorescence of carbonate of soda, which is sometimes seen on old walls, or which in some countries is found on the soil, appears to have originated in this manner." (*Turner*.)

Such a view of the partition of acids and bases among each other may and does probably take place in many cases; but it may be shown that it does not always occur; for Dr. Struve has observed at his establishment in Dresden for the preparation of artificial saline and carbonated waters, that their taste depends not only on the nature of the salts, but also upon the order in which they are added. The prevailing opinion at present, sustained by the medical effects of mineral waters, is, that the strongest acid is combined with as much of the strongest base as it finds present, then with the next strongest, and the weaker bases and acids are separately united. In setting up the composition of a mineral water from analysis, this principle is generally employed.

Gmelin ascribes the influence of insolubility in part, to a *predisposing affinity of the solvent*, and among others gives the following example. Dilute acetic acid decomposes carbonate of potassa, forming acetate of potassa, and evolving carbonic acid; but if the dry acetate of potassa be dissolved in alcohol, and carbonic acid passed through it, nearly all the potassa is precipitated as carbonate, and the acetic acid is retained by the alcohol, partially converted into acetic ether. The alcohol appears to exert a considerable affinity for the acetic acid, and when added to that of the carbonic acid for potassa, they overcome the affinity of the acetic acid for the potassa. Berthollet's view is generally applied to this fact, viz., that the carbonate of potassa being insoluble in alcohol must precipitate. Gmelin asks, "why does not the carb. acid precipitate from an aqueous solution of acetate of lime the carbonate of lime, which is more insoluble in water than the carb. potassa is in alcohol?" According to Pelouze, carb. acid does not precipitate the alcoholic solutions of chlorides of strontium or calcium, nor nitrate of copper, although the carbonates of those metallic oxides are insoluble in water and alcohol. The above shows that insolubility and great cohesion are

not identical, for then the carbonate of potassa would be a very coherent salt in reference to alcohol, and slightly coherent in reference to water. (*Gmelin*).

2. *Temperature* modifies affinity in two ways, either by producing a gaseous or elastic fluid, or by increasing or diminishing cohesion; but often exhibits a reciprocal action which is explained with difficulty. The last are sometimes called instances of *reciprocal affinities*; and Gmelin is disposed to refer them to a combination of heat with one of the constituents, regarding heat as a body.

Elasticity. From the obstacle which cohesion puts in the way of affinity, the gaseous state, in which the cohesive power is wholly wanting, might be expected to be peculiarly favorable to chemical action. The reverse, however, is the fact. Bodies generally evince little disposition to unite when presented to each other in the elastic form. Oxygen and hydrogen gases, and chlorine and hydrogen, though their mutual affinity is very powerful, may be preserved together for any length of time without combining. This want of action seems to arise from the distance between the particles preventing that close approximation which is so necessary to the successful exercise of affinity. Hence many gases cannot be made to unite directly, which nevertheless combine readily while in their *nascent* state; that is, while in the act of assuming the gaseous form by the decomposition of some of their solid or fluid combinations.

Elasticity operates likewise as a decomposing agent. If two gases, the reciprocal attraction of which is feeble, suffer considerable condensation when they unite, the compound will be decomposed by very slight causes. Chloride of nitrogen, which is an oil-like liquid, composed of the two gases chlorine and nitrogen, affords an apt illustration of this principle, being distinguished for its remarkable facility of decomposition. Slight elevation of temperature, by increasing the natural elasticity of the two gases, or contact of substances which have an affinity for either of them, or angular bodies, produces immediate explosion.

Many solid substances which contain water in a state of intimate combination part with it in a strong heat, in consequence of the volatile nature of that liquid. The separation of oxygen from some metals, by heat alone, is explicable on the same principle. (*Turner*.)

Binoxide of manganese with chlorohydric acid produces chlorine, water, and chloride of manganese at common temperatures or by gentle warmth; on the other hand, chlorine and water exposed to light or ignition, produce chlorohydric acid or oxygen. Such reciprocal affinities are not uncommon, and produce singular and unexpected changes. Potassium decomposes magnetic oxide of iron at a red heat into potassa and metallic iron; but metallic iron and potassa at a white heat are resolved into magnetic oxide of iron and vapor of potassium. Potassium decomposes carbonic oxide at a red heat, into potassa and carbon; potassa and carbon at a low white heat produce carbonic oxide and vapor of potassium. Carbonate of ammonia, and nitrate of lime in

solution, produce carbonate of lime and nitrate of ammonia, partly from the insolubility of the former; but by heating nitrate of ammonia and carb. lime above 212° , the carb. ammonia is evolved, being more volatile than the nitrate. Phosphated, borated, or silicated alkali is decomposed by sulphuric acid at common temperatures, the acid being set free, and a sulphated alkali being formed; but the sulphated alkali ignited with phosphoric, boracic, or silicic acid forms a salt with it, while the more volatile sulphuric acid is evolved.

Pressure is sometimes supposed to exert some influence where an elastic body is evolved. Zinc, sulphuric acid, and water, usually evolve hydrogen from the water, but if the operation be performed in a strong and closed metallic vessel, the generation of hydrogen progresses until its atmosphere causing a considerable pressure, it ceases to evolve. (*Babinet.*) Faraday doubts the cessation, and ascribes the diminished evolution of gas to diminished effervescence, by the movement of which chemical action is assisted. Gmelin proved by an experiment with muriatic acid and zinc that hydrogen continued to be evolved at a pressure of 50 atmospheres, which is beyond that assigned by Babinet. Berzelius also observes that the action of a somewhat diluted acid on carbonate of lime in a closed glass tube ceases in consequence of pressure; but an experiment by Gmelin proved that the evolution went at least so far as to produce liquid carbonic acid. It does not therefore appear to be shown satisfactorily that pressure exerts a higher influence than merely rendering the evolution of gas slower.

Cohesion affected by temperature. This refers chiefly to solutions of different salts. A solution of common salt and sulphate of magnesia evaporated at common or slightly elevated temperatures, separates the two crystallised salts unaltered; but at 32° and below, sulphate of soda crystallises out and leaves chloride of magnesium in solution; above 122° , the mixed solutions again deposit sulphate of soda, but anhydrous. Solubility determines this peculiarity; for the sulphate of soda is less soluble at a low and a high than at a medium temperature. Sulphate of soda, and chloride of potassium change at common temperatures into sulphate of potassa and chloride of sodium; but at about 0° F. sulphate of soda separates; the sulphate of potassa being more insoluble in the former case, and the sulphate of soda at 0° .

Aqueous solutions of sulphate of lime and chloride of barium mingled together, precipitate sulphate of baryta, and chloride of calcium remains dissolved. By fusing together chloride of calcium and sulphate of baryta, there is formed a mixture of sulphate of lime and chloride of barium; which may be extracted by rapidly boiling the powdered mass with water, and filtering; but longer contact with water produces again sulphate of baryta and chloride of calcium. A solution of acetate of alumina does not become clouded when heated, but readily precipitates when a sulphated alkali is present. (See *Acetate of Alumina.*) The precipitate, consisting of hydrate

of alumina, appears every time it is heated and re-dissolves on cooling. Metallic silver abstracts oxygen from an aqueous solution of persulphate of iron at a boiling heat, forming sulphate of silver and protosulphate of iron; but all the silver precipitates on cooling in the metallic form. Some of these and similar instances of reciprocal attraction are difficult to explain.

It appears then, that heat generally influences affinity in two different ways, by assisting or diminishing it, and yet they are both referrible to the same principle; applied to solids to render them liquid, and sometimes to liquids, it usually promotes affinity by reducing cohesive force, and promoting mobility of particles, but where it generates gaseous matter it opposes affinity by separating the particles beyond the sphere of attraction. The liquid state therefore, being intermediate between the greatest and least cohesive force, is best adapted to chemical action.

3. *Relative quantity of matter acts in two ways, by diffusion or affinity.*

Diffusion. When steam is passed over iron at a red heat, a portion of it is decomposed, black oxide of iron being formed and hydrogen gas evolved. From this experiment it might be inferred that the affinity of iron for oxygen is greater than that of hydrogen. But let a stream of hydrogen gas be conducted over black oxide of iron at the very same temperature, and water is formed, while the oxide of iron is reduced to the metallic state. Here the hydrogen appears to have the greater affinity for oxygen. But the result is obviously connected with the relative proportion between the hydrogen and steam which are at once in contact with the metal and its oxide at a red heat. When steam is in excess, water is decomposed, but when hydrogen is in excess, oxide of iron is decomposed; because the excess of steam in the first case is an atmosphere into which hydrogen can *diffuse*, and the disengagement of that gas is therefore favored; but in the second case the atmosphere is principally hydrogen, and represses the evolution of more hydrogen, but facilitates that of steam. The affinity of iron and hydrogen for oxygen at the temperature of the experiment, is so nearly balanced that the one affinity prevails over the other, according as there is a proper atmosphere into which the gaseous product of its action may diffuse. (*Guy-Lussac and Regnault in Graham.*) According to Despretz, zinc, tin, nickel, and cobalt act similarly to iron; cadmium and uranium also (*Regnault*), although they decompose water with difficulty. Zinc, tin, and iron, act similarly to carbonic acid and oxide, being oxidized in the former, and reduced to metal in the latter. If carbonate of lime be heated in a tube to a point just below where its acid is given off, steam or air passed over it will then remove the carbonic acid. Aqueous chlorohydric acid decomposes metallic fluorides, and aqueous fluohydric the metallic chlorides; chlorohydric acid decomposes the acetates, and acetic acid the chlorides; but the decomposing acid must always be in excess in order that the liberated acid may be carried off by diffusion.

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Affinity. If 1 eq. nitric acid be added to an aqueous solution of 2 eq. of sulphate of alkali, the odor of the acid disappears, and by spontaneous evaporation crystals of nitrate of alkali separate, while a bisulphate remains in solution. But if 2 eq. sulphuric acid be added to 1 eq. nitrate of alkali, the whole of the nitric acid is disengaged, and a bisulphate remains in solution; one eq. of sulphuric removes only $\frac{1}{2}$ the nitric acid, so that a nitrate and bisulphate would remain. There appears here to be a partition of the acids, with the base as explained above (*Influence of cohesion*); or the affinity to form a bisulphate, together with the affinity to form a neutral nitrate preponderate over the affinities required to form only neutral salts.

4. *Predisposing Affinity.* Zinc decomposes water at ordinary temperatures with extreme slowness, becoming oxidized, and liberating hydrogen; but as soon as sulphuric acid is added, the gas is evolved with rapidity. This was formerly explained by supposing that the addition of acid disposed the metal to decompose water, in order to unite with the oxide of zinc; thus attributing to it an influence over a body previous to its existence, and hence, for want of a better explanation, it was termed predisposing affinity. There can be little doubt that the changes, that is, the formation of oxide of zinc and its union with sulphuric acid, follow each other so immediately that we may regard them as simultaneous and not consecutive, and hence the subject has been explained in this manner, by considering the formation of oxide and its union with acid as proceeding at one and the same instant of time, and that the two affinities acting conjointly overcome that between oxygen and hydrogen. Such an explanation is evidently no better than the other, unless it can be shown that oxide of zinc is formed the moment the metal is put into water alone, for otherwise there can be but one affinity, that of zinc for oxygen, the other not existing previous to the formation of oxide. But it has been shown that zinc does not decompose water at ordinary temperatures, provided the air be excluded; and even in water containing air, the oxidation is so tardy that it requires the lapse of some time before oxide can be detected on its surface.

There are two other explanations of a more satisfactory character. 1st. That the change which takes place is simply the substitution of zinc for hydrogen in the oil of vitriol (sulphate of water), forming sulphate of the oxide of zinc instead of the oxide of hydrogen, and that the large quantity of water employed is useful to dissolve the sulphate of zinc, and permit the free play of affinities; the proportions usually employed are an eq. of acid and zinc, and some 25 eq. water, of which probably 7 are required for the crystallised sulphate of zinc, and the balance employed for solution. Such an explanation may serve better for the above than for the following decomposition: Phosphorus cannot remove all the oxygen from carbonic acid at any temperature, but phosphoric acid is decomposed by ignition with carbon into carbonic oxide and phosphorus; if phosphorus be boiled with carbonate

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of soda it abstracts oxygen and deposits carbon, and when vapor of phosphorus is passed over ignited carbonate of soda (or lime), it exhibits combustion, forming phosphate of soda and depositing carbon. Now the presence of soda causes the difference of action, and predisposes the formation of phosphoric acid in order to unite with it, for the soda has a stronger affinity for the phosphoric than for the carbonic acid; in other words, the soda attracts the phosphoric acid previous to its existence, although it is already combined with an acid. This fact is not readily explicable by any of the above theories, predisposition, simultaneous action, or substitution.

2d. That the instances of predisposing affinity may be explained by the chemical theory of contact; thus, the contact of the acid with the zinc gives it a higher electropositive power to abstract oxygen from water, like potassium; the contact of soda gives the phosphorus a higher negative power to decompose carbonic acid, which it could do imperfectly without it.

In whatever light we view the subject, it is beset with difficulties; until these are removed we may adopt the contact theory, which explains all the facts better than any other; still it requires farther substantiation.

VI. CIRCUMSTANCES AND CONSEQUENCES OF DECOMPOSITION.

1. *Change of Temperature.* Since evolution of heat accompanies combination, it might be inferred that it would be absorbed, or produce cold by decomposition; the reverse, however, takes place, since heat is evolved by decomposition and often amounts to combustion. Decompositions generally result from the introduction of new and preponderating affinities, and hence it is easy to explain on the principle of heat evolved by combination, how heat should also be disengaged by such decompositions. When a body dissolved is again separated in the solid form, we may easily suppose the heat evolved to be the heat of fluidity, which the body had previously absorbed by solution. It is, however, difficult to explain the evolution of heat in all instances; thus, when binoxide of hydrogen is resolved into water and oxygen gas, by dropping into it pulverulent substances, although much heat should become latent upon its assuming the gaseous form, it evolves heat largely and even light. Gmelin supposes that by its combination with water heat is absorbed and not given off.

2. *Change of Nature.* Bodies become gaseous, liquid, or solid by decomposition. If gaseous, and the change be not very rapid, it gives rise to effervescence; muriatic acid on carbonate of lime or in a strong solution of carbonate of alkali. See EFFERVESCENCE. When gaseous and very rapid with a hissing noise, it is DEFLAGRATION (which see); if the gas is given off in an instant of time, it is an explosion, such as fulminate of silver, chloride of nitrogen, and chlorous acid gas. See DETONATION and EXPLOSION. When liquids are the result of decomposition they form a cloudy mixture, which afterwards separates into a strata according to their spec. gravities. When a solid is produced from a liquid, it is a PRECIPITATE (see this).

VII. MEASURE OF AFFINITY.

It will be readily seen by a glance at the circumstances which influence and modify affinity, that, although affinity is a determinate force, it is difficult to measure it relatively to other natural forces, and impossible in the present state of our knowledge to determine it absolutely. We may subsequently be able to attach a number to each substance, expressive of its force towards other substances without reference to other forces, but we can only determine at present, with moderate certainty, the general order of affinities among bodies in reference to each other.

1. It may be measured by observing the phenomena of decomposition, uninfluenced by other disturbing causes, on the principle that the divellent are superior to the quiescent affinities. Heat may produce a measurable change. The tersulphuret of gold loses all its sulphur at about 840° ; now taking the boiling point of sulphur at 820° , the affinity of gold and sulphur would be $840 - 820 = 20$. The bisulphuret of iron FeS_2 loses so much sulphur at about 930° that another sulphuret remains Fe_7S_8 , but at about 1500° (?) it loses the excess and there remains FeS (protosulphuret of iron); then the affinity of FeS (or Fe_7S_7) to so much sulphur as to produce Fe_7S_8 is expressed by $1500 - 820 = 680$, and that of Fe_7S_8 to produce FeS_2 (or Fe_7S_{14}) by $930 - 820 = 110$. Most bases lose carbonic acid at a low red heat,

lime at a stronger, strontia at a still stronger, baryta only at a forge heat, and soda and potassa at no temperature; the two last have therefore the strongest affinity for carbonic acid, and when the earthy bases in water decompose the alkaline carbonates, it is because water has a more powerful affinity for soda and potassa.

It is usually measured by elective affinity. *Single elective.* When AB is decomposed by C, and AC by D, and AD by E, it would follow that A has the strongest attraction for E, feebler for D, more so for C, and feeblest for B, so that upon comparing these affinities together under different combinations a general table of affinities might be constructed. Thus, carbonate of lime loses its carbonic acid by muriatic, the muriatic loses its muriatic by sulphuric, and the sulphate in solution is decomposed by oxalic acid, so that a table of the affinities of lime would give the acids in the following order of strength: oxalic, sulphuric, muriatic, and carbonic. See *Single Elective Affinity*. But the collateral influence of cohesion, elasticity, &c., so modify these decompositions that such tables would be useless. *Double Elective* (see it also above). Morveau assumed that in the mutual decomposition of two salts, the sum of the two divellent must exceed that of the two quiescent affinities, and endeavored to express by numbers, the amounts of affinity ascertained by decomposition, as in the following table of the attractions of acids for bases:

	Sulphuric.	Nitric.	Chlorohydric.	Acetic.	Carbonic.
Baryta.....	66	62	36	28	14
Potassa.....	62	58	32	26	9
Soda.....	58	50	31	25	8
Lime.....	54	44	24	19	12
Ammonia.....	46	38	21	20	4
Magnesia.....	50	40	22	17	6
Alumina.....	40	36	18	15	2

According to this table sulphate of soda and chloride of barium should mutually decompose, because $66 + 31 = 97$ is greater than $58 + 36 = 94$. But that such tables do not express the true measure of affinities is evident, for with sulphate of potassa and nitrate of baryta the divellent and quiescent affinities are balanced ($62 + 62 = 66 + 58$), and yet decomposition does take place; and again, with sulphate of soda and nitrate of baryta the divellent affinities, $66 + 50$, are less than the quiescent, $58 + 62$, although decomp. occurs.

2. Morveau attempted to determine the amount of affinity by *Adhesion*, which he regarded as incipient affinity. By placing equal plates of different metals in contact with mercury, he observed the several amounts of weight requisite to separate them, which he regarded as expressive of their relative affinities. Although the attractions of the metals for mercury, which he tried, are nearly in his order, yet it does not prove him to be right, for sulphur has a stronger attraction for mercury than any one of them, and yet it would require less weight to break its contact. Moreover, it is not by any means shown that adhesion and affinity bear a uniform relation to each other, although it may be shown that there is an alliance between them not fully understood, and

that the phenomena of solution form a connecting link between capillary attraction and affinity. See *Adhesion*, and *Amalgam*.

3. Wenzel attempted to measure affinity by the time required for combination, but the collateral circumstances attending the solutions of metals are too many and indefinite in themselves to admit of accuracy in the experiments, and of course in the inferences.

4. Affinity has also been measured by the relative quantities of bodies which unite, and Berthollet supposed it to be inversely as the power of neutralization. Thus, when a certain quantity of acid, A, is neutralized by 1 of base B, 2 of base C, 3 of D, the affinities of A to B, C, and D are relatively 3, $1\frac{1}{2}$, 1. Bergman established two laws from his experiments, which were exactly the reverse of Berthollet, viz. that an acid has the greatest affinity for that base of which it requires the greatest quantity for neutralization, and that a base has the same relative affinity for acids. Kirwan adopted the view of Bergman for acids, but the reverse for the affinities of bases for acids. The order of affinity, as established by double decomposition, and the extended knowledge we at present possess of combining weights and other circumstances connected with affinity refute these laws.

There are a few general laws which seem to result from the amount of affinity. 1. If one body combines with two or more proportions of another, they exhibit the strongest affinities in their least combining proportion, and a diminished power in proportion to the number of equivalents. Carbonic acid CO_2 is more easily decomposed than CO ; manganic acid (MnO_3) in solution, readily parts with oxygen at ordinary temperatures, forming binoxide of manganese (MnO_2); which again loses oxygen by a strong red heat, becoming brown oxide (Mn_3O_4); and by the use of sulphuric acid, the last, or any of the preceding, loses $\frac{1}{2}$ more and is reduced to the lowest stage of oxidation (MnO), from which oxygen is obtained with great difficulty by the most powerful heat and a reducing agent combined. There are a few apparent exceptions to this law; nitrous oxide loses its oxygen at a lower temperature than nitric oxide, nitrous acid than nitric, perchlorate of potassa than chlorate, &c.; but closer observation shows the law to be universal. 2. The elements generally exhibit the strongest affinity for each other; then follow simple salts consisting of an acid and a base, while double salts often evince very feeble affinities. Thus oxygen, chlorine, sulphur, &c., have powerful affinities for the other elements; sulphuric, nitric, &c., acids, strong affinities for potassa, oxide of lead, &c.; alum, bi-salts, double chlorides, &c., are more easily decomposed. But the different strengths of these affinities depends upon another general law: 3. That the more opposite bodies are in their physical characters, the stronger in general their affinities; thus the acids, with little attraction for each other, have a powerful one for bases, and bases the same for acids, although with feeble affinity for each other; the metals generally evince a feeble attraction for each other, much more for those with fewest metallic characters, and a very powerful affinity for the metalloids.

Tables of Affinities. The following tables of the order of affinities beginning with the strongest, can only be regarded as a distant approximation to a correct measure of relative affinity. They are represented by formula for brevity. Where separated by commas, the exact order has not been determined among them.

Oxygen, for K; Na, L?; Ba, Sr, Ca; Mg, Y, G, Al, Th, Zr, Si; B; C; Ti, Ta, W, V, Cr, Mn; CO, H; MO; Zn; Fe; Cd; Ni; Co; Sn; TaO_2 ; MnO ; MoO ; TiO ; P; Pb; Bi; Sb; PO_3 ; S; Cu; MoO_2 ; As; N; SnCl ; SO_2 ; WO_2 ; NO; Se; Pt, Ir; FeO ; Hg; Fe; Os; R; Pd; Ag; KO; BaO; AsO_3 ; I; NO_4 ; Cr_2O_3 ; V_2O_3 ; Au; Br; Cl; F; IO_5 ; ClO_5 ; HO.

Chlorine for alkaline metals; earthy metals; Ti; Zn; Fe; Cd; Co; Sn; CuO ; H; P; Pb; Bi; Sb; S; Cu; Hg; As; Ag; SnCl ; Hg_2Cl ; Pd; Pt; Au; I; Br; O.

Fluorine, Bromine, and Iodine, are similar to chlorine in their affinities.

Sulphur for O; alkaline metals; Zn; Fe; Sn; Cu; Cl; H; C; Pb; Bi; Sb; Hg; Ag; Pt; Cu_2S ; MoS_2 ; Au.

Phosphorus, O; Cl; Br; I; K; Zn; S; H.

Hydrogen, O; F; Cl; Br; I; Se; S; P; As; Sb; N.

Nitrogen, C; H; I; Br; Cl.

Metals, O; F; Cl; Br; I; Se; S; P; H. Different metals exhibit a different order, and this table is only very general.

Sulphuric acid, BaO; SrO; KO; NaO, LO?; CaO; MgO; PbO; NH_3 ; FeO; ZnO; NiO; CoO; CuO; Al_2O_3 ; Fe_2O_3 .

Chlorohydric acid, 4PbO; KO; NaO; BaO; SrO; CaO; MgO; NH_3 ; CoO; NiO; HgO ; MnO; ZnO; FeO; UO; Cu_2O ; CuO; SnO; G_2O_3 ; Al_2O_3 ; U_2O_3 ; Cr_2O_3 ; Fe_2O_3 ; SnO₂; SbO_3 .

Nitric acid, KO; NaO; LO; BaO; SrO; 6PbO; CaO; MgO; NH_3 ; AgO; CoO; NiO; ZnO; MnO; CdO; CuO; G_2O_3 ; Al_2O_3 ; U_2O_3 ; Cr_2O_3 ; Hg_2O ; HgO ; Fe_2O_3 .

Potassa, 2MoO₃; 2SO₃; 2CrO₃; 2C₂O₃; 2 Tartaric acid; SO₃; SeO₃; NO₃; IO₇; ClO₇; HF; HCl; PO₅; AsO₅; IO₅; BrO₅; ClO₅; HBr; CrO₃; PO₃; HI; SeO₃; NO₃; SO₂; MnO₃; BO₃; CO₂; AsO₃; HSe; HS; HCy. This table is far from being exact. (See *Gmelin's Chemie*, vol. i., art. *Affinität*, p. 31 to 155, for a very full and condensed view of the whole subject of Affinity.)

AGALMATOLITE. *Min.* Syn. Figure-stone. *Ger.* Bildstein, Agalmatolith. *Fr.* Talc graphique. Steatite Pagodite.

Massive, structure sometimes slaty.

H = 2 and less. Spec. grav. = 2.815 Klaproth; 2.895 Thomson.

Color, grayish, greenish, yellowish (brownish) white, rarely pink or mottled; *lustre*, waxy, nearly dull; translucent on the edges; *touch*, unctuous; *streak*, nearly white, somewhat shining; *fracture*, coarse, splintery; sectile.

Chem. Bl. P. In flask blackens and yields empyreum-water: on charcoal burns white, fine-scaly on surface, traces of fusion on edges; with borax a colorless glass; mic. salt does not decompose it but shows strong effervescence; with soda swells, fuses with difficulty to a cloudy glass, which, with a certain quantity of soda is clear; with cobalt shows the presence of magnesia. *Decomp.* Not perceptibly attacked by chlorohydric or sulphuric acids; dissolves in hot sulphuric, leaving silica.

Analysis.	By Vauquelin.	Klaproth.	Thomson.	Lychnell.
Silica	56	54.5	49.816	72.40
Alumina	29	34.0	29.596	24.54
Potassa	7	6.25	6.8	
Lime	2	—	6.0	
Oxide of iron	1	.75	1.5	2.85
Water	5	4.0	5.5	
	100	99.50	99.212	99.79

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A comparison of these analyses, supposing them to be correct, shows that agalmatolite is a compound of several minerals in variable proportions. Lychner endeavoured to establish a formula on his analysis which makes it a neutral silicate of alumina; but, although agreeing with his, it would not apply to the other analyses. It yet remains undecided whether it is a simple mineral of invariable constitution, sometimes mixed with foreign matter, or composed of several minerals mixed or combined.

Use and Local. Chiefly found in China, where it is carved into grotesque figures and ornaments. Found also at Nagyag in Transylvania, Norway, Wales.

AGARIC MINERAL. *Min.* See **CARBONATE OF LIME.**

AGARICUS. *Bot. Chem.* See **MUSHROOM.**

AGATE. *Min.* See **QUARTZ, AGATE.**

AGEDOILE. *Chem.* A crystalline substance found by Robiquet in liquorice-root, and shown by Plisson to be identical with **ASPARAGINE**, to which refer.

AGENT. *Chem.* A substance, whether elementary or compound, which is employed to effect chemical changes. The imponderables may be employed as agents; heat effects decomposition in red oxide of mercury, promotes union between sulphur and metals; light blackens salts of silver, unites chlorine and hydrogen; electricity decomposes water, unites oxygen and hydrogen to form water. It is more generally applied to ponderable matter of a uniform character; thus, hydrogen and carbon are useful agents for decomposing the oxides; sulphuric acid is one of the most useful agents to the chemist from its strong affinities, its abundance, &c. They are sometimes termed *reagents*, from the reactions or decompositions which they produce, and this term is frequently applied to the tests used in qualitative analysis.

AGGREGATE. *Chem.* Either a union, a heap, of independent particles, or a union of homogeneous particles to a homogeneous body without reference to the independent nature of each particle. The latter is the more probable and the prevailing view at present. In geology the term is sometimes applied to rocks, which are aggregates of different simple minerals.

AGGREGATION. *Chem.* The act of union of homogeneous particles into an aggregate. The *state of aggregation* is the condition of a body determined by the manner in which the particles are united. Bodies exist in three states: solid, liquid, or gaseous, according to the amount of cohesion among their particles. In solids the cohesion often requires a considerable external force to separate the particles, each of which is still possessed of the same cohesive force independently of the others, so that the portions of a fractured solid resemble the aggregated whole. In liquids the cohesive force is so diminished that they barely cohere together, their particles move freely among each other, and their form depends on the equilibrium between the cohesion of their particles and external forces. The particles of a gas have no cohesive force, but rather a repulsion, and hence its form depends wholly on external

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forces, such as gravitation, enclosure in a vessel, without which its particles would entirely separate. See **COHESION.**

AGRICULTURE. The late admirable essay of Liebig on agricultural chemistry is about to produce an important change in the practice of agriculture, by the application of chemical principles; and the student of elementary chemistry should be acquainted with these views, as well to obtain an expanded idea of this science, as to give his assistance to the further development of its principles in their application to agriculture.

"The development," says Liebig, "of the stem, leaves, blossoms, and fruit of plants is dependent on certain conditions, the knowledge of which enables us to exercise some influence on their internal constituents as well as on their size. It is the duty of the natural philosopher to discover what these conditions are; for the fundamental principles of agriculture must be based on a knowledge of them. There is no profession which can be compared in importance with that of agriculture, for to it belongs the production of food for man and animals; on it depends the welfare and development of the whole human species, the riches of states, and all commerce. There is no other profession in which the application of correct principle is productive of more beneficial effects, or is of greater and more decided influence.

"In addition to the general conditions, such as heat, light, moisture, and the component parts of the atmosphere, which are necessary for the growth of all plants, certain substances are found to exercise a peculiar influence on the development of particular families. These substances either are already contained in the soil, or are supplied to it in the form of the matters known under the general name of manure. But what does the soil contain, and what are the components of the substances used as manure? Until these points are satisfactorily determined, a rational system of agriculture cannot exist. The power and knowledge of the physiologist, of the agriculturist and chemist must be united for the complete solution of these questions; and, in order to attain this end, a commencement must be made.

"The *general* object of agriculture is to produce in the most advantageous manner certain qualities, or a maximum size, in certain parts or organs of particular plants. Now, this object can be attained only by the application of those substances which we know to be indispensable to the development of these parts or organs, or by supplying the conditions necessary to the production of the qualities desired.

"The *special* object of agriculture is to obtain an abnormal development and production of certain parts of plants, or of certain vegetable matters, which are employed as food for man and animals, or for the purposes of industry.

"The means employed for effecting these two purposes are very different. Thus the mode of culture employed for the purpose of procuring fine pliable straw for Florentine hats, is the very opposite to that which must be adopted in order to produce a maximum of corn from the same plant."

There are two prevailing views in reference to the nutriment of plants, the one regarding it as wholly derivable from inorganic matter, the other as partly from organic and partly inorganic. The former of these views has been so ably advocated by Liebig by reference to numberless chemical and physiological data, that a majority of chemists adopt them, and even should they prove not wholly correct, it is easy to foresee that his essay will revolutionize agriculture and vegetable physiology; Boussingault, Saussure, &c., maintain that nutriment is partly derived from organic matter in the soil. We shall first present a condensed view of Liebig's essay, and subsequently the opposite opinion.

NUTRIMENT DERIVED SOLELY FROM INORGANIC MATTER.

There are 4 elements which in general form the organic matter of plants: carbon, hydrogen, oxygen, and nitrogen, 2 or more of which united in variable proportions constitute an almost infinite number of proximate principles. Plants derive nourishment from the atmosphere and the soil. The former consists of nitrogen and oxygen, with a small quantity of carbonic acid ($\frac{1}{1000}$ of its weight), and a minute quantity of ammonia; the soil is the source of the inorganic solid and liquid matters, and beside its earthy constituents contains decaying organic matter called humus, which was supposed to be the cause of fertility.

Assimilation of Carbon. Humus is soluble in an extremely minute degree in water, but when treated with alkalis, the humic acid formed is somewhat soluble. Suppose this acid to be absorbed in the form of that salt which is most soluble, the humate of lime, and suppose that potassa, soda, the oxides of iron and manganese take up the same quantity of the acid as lime, Berthier found that 1000 lbs. of dry fir-wood yielded 4 lbs. ashes, containing 53 per cent. metallic oxides. A Hessian acre yields annually 2920 lbs. fir-wood, containing 6.17 lbs. metallic oxides. Then 1 lb. of lime, uniting with 12 lbs. humic acid, the 6.17 lbs. of the oxides would introduce 74 lbs. humic acid, which, containing 58 per cent. carbon, would correspond to 100 lbs. of wood; but the acre really yields 2920 lbs. In the same way the oxides in wheat straw would produce 93.6 lbs. woody fibre to the acre, whereas the produce is 1961 lbs. of straw composed similarly to woody fibre.

Calculating the quantity of this acid which plants might receive under the most favorable circumstances by the agency of rain-water, and supposing all the rain which falls on an acre to be received by the plants, and all to be saturated by humate of lime, then the plants would receive only 330 lbs. humic acid, while the acre produces 2843 lbs. of grain and straw, so that the 330 of acid would only account for a small quantity of the carbon actually obtained.

Again, the Hessian acre of wood or meadow yields 1109 lbs. carbon in its wood or hay,—1032 in the beet-root without the leaves, or 1124 lbs. in straw and grain; equal surfaces of average fertility yielding equal quantities

of carbon; and yet the conditions in the growth of these plants have been very dissimilar.

Moreover, the soil of meadow and forest, instead of losing carbon, actually increases its quantity, notwithstanding the removal of so much in the wood or hay, and the soil of a field which is manured contains no more than a meadow or forest which is not manured.

These considerations prove that the common view of the nutrition of plants by humic acid is incorrect. Whence, then, is their carbon derived?

The quantities of carbonic acid in the air averages 4 vols. in 10,000 vols., so that the weight of carbon which presses on an acre of land is about 7 tons. The quantity of oxygen estimated to be consumed by the respiration of 1000 millions of men in one year is 0.79745 cubic miles. A town of 7000 inhabitants consumes annually 551 millions cubic feet of oxygen in the combustion of wood. Hence we may conceive of the enormous quantity of carbonic acid constantly thrown into the air by the respiration of men and animals, by combustion, and the putrefaction of animal and vegetable matter. Now, analysis shows that the quantity of oxygen is the same now as it was 1000 years since. There must be, therefore, some means of replacing the oxygen consumed, and of removing the carbonic acid which is formed.

Plants effect both of these changes, absorbing carbonic acid, decomposing it and giving off oxygen. A plant placed in water containing carbonic acid, and exposed to the sun's light, removes the acid and evolves oxygen, which may be collected in a receiver and examined; it increases in weight more than can be accounted for by the carbon taken up, which shows that the elements of water are assimilated at the same time. The quantity of carbon in the air may be shown to be 3300 billions of lbs., which is more than all the plants and the strata of coal on the earth. Calculating from the quantity of carbonic acid absorbed by a freshly white-washed surface in a given time, a Hessian acre might absorb in 200 days 11.353 lbs. carbonic acid, containing 3304 lbs. carbon, which is 3 times as much as obtained from plants growing on the same surface.

Carbonic acid is absorbed from the air by the leaves, and from the soil by the roots, for it forms an atmosphere in the soil around decaying humus. When exposed to sun-light it is decomposed while oxygen is evolved, but at night this action ceases, and the acid is emitted while oxygen is absorbed. The emission of the acid is a simple mechanical process, the absorption of oxygen a chemical process, due to its action on the various organic substances in the flowers, fruits, &c., but neither have any thing to do with the process of assimilation. Thus volatile oils, tannin, &c., have a tendency to oxidize, and hence plants containing them absorb more oxygen than others; the tasteless leaves of the *Agave Americana* absorb 0.3 of their volume of oxygen in the dark during 24 hours, the leaves of the *Pinus abies* absorb 10 times, and those of the *Quercus Robur* 14 times their volume.

These and other facts prove that the quantity of oxygen thrown into the atmosphere by plants, is greater than that which they receive from it.

To conclude, the carbon contained in plants is derived from the carbonic acid of the atmosphere, through the leaves or from that contained in the soil through the roots.

Origin and Action of Humus. All plants and vegetable structures undergo two processes of decomposition after death. One of these is named *fermentation*; the other, *putrefaction*, *decay*, or *eremacausis*.

The decay of woody fibre (the principal constituents of all plants) is accompanied by a phenomenon of a peculiar kind. This substance, in contact with air or oxygen gas, converts the latter into an equal volume of carbonic acid, and its decay ceases upon the disappearance of the oxygen. If the carbonic acid is removed, and oxygen replaced, its decay recommences, that is, it again converts oxygen into carbonic acid.

Woody fibre in a state of decay is the substance called *humus*. Its property of converting surrounding oxygen gas into carbonic acid diminishes in proportion as its decay advances, and at last a certain quantity of a brown coaly-looking substance remains, in which this property is entirely wanting. This substance is called *mould*; it is the product of the complete decay of woody fibre.

Humus is a continued source of carbonic acid, which it emits very slowly. An atmosphere of carbonic acid is therefore contained in every fertile soil, and is the first and most important food for the young plants which grow in it.

The roots perform the functions of the leaves from the first moment of their formation: they extract from the soil their proper nutriment, namely, the carbonic acid generated by the humus.

By loosening the soil which surrounds young plants, we favour the access of air, and the formation of carbonic acid, which is absorbed, and is replaced by atmospheric air, by which process the decay is renewed, and a fresh portion of carbonic acid formed. A plant at this time receives its food both by the roots and by the organs above ground, and advances rapidly to maturity.

When a plant is quite matured, and when the organs by which it obtains food from the atmosphere are formed, the carbonic acid of the soil is no further required.

The power which roots possess of taking up nourishment does not cease as long as nutriment is present. When the food of a plant is in greater quantity than its organs require for their own perfect development, the superfluous nutriment is not returned to the soil, but is employed in the formation of new organs. At the side of a cell, already formed, another cell arises: at the side of a twig and leaf, a new twig and a new leaf are developed.

The functions of the leaves and other green parts of plants, to absorb carbonic acid, and with the aid of light and moisture, to appropriate its carbon, are continually in operation. But the new products arising from this con-

tinued assimilation are no longer employed by the perfect leaves in their own increase: they serve for the formation of woody fibre, and all the solid matters of similar composition. The leaves now produce sugar, amylin or starch, and acids, which were previously formed by the roots, when they were necessary for the development of the stem, buds, leaves, and branches of the plant.

The organs of assimilation, at this period of their life, receive more nourishment from the atmosphere than they employ in their own sustenance; and when the formation of the woody substance has advanced to a certain extent, the expenditure of the nutriment, the supply of which still remains the same, takes a new direction, and blossoms are produced. The functions of the leaves of most plants cease upon the ripening of their fruit, because the products of their action are no longer needed. They now yield to the chemical influence of the oxygen of the air, generally suffer a change in colour, and fall off.

A peculiar *transformation* of the matters contained in all plants takes place in the period between blossoming and the ripening of the fruit; new compounds are produced, which furnish constituents of the blossoms, fruit, and seed. An organic chemical transformation is the separation of the elements of one or several combinations, and their reunion into two or several others, which contain the same number of elements, either grouped in another manner, or in different proportions. Of two compounds formed in consequence of such a change, one remains as a component part of the blossom or fruit, while the other is separated by the roots in the form of excrementitious matter.

Hydrocyanic acid and water are decomposed by contact with muriatic acid into formic acid and ammonia; the muriatic seeking to be saturated by a base, selects the elements nitrogen and hydrogen to form ammonia, with which it unites, and its power of producing farther change is lost. By the separation of ammonia, the remaining elements unite to produce formic acid. The ammonia represents the substance assimilated by the plant, and the formic acid the excrementitious matter.

By means of chemical transformations a great variety of products may now be obtained artificially, which, having been found in plants and animals, were supposed to result from the vital principle. The volatile oil of valerian may be obtained from the oil generated during the fermentation of potatoes; the oil of *Spiræa ulmaria* from the crystalline matter of the bark of the willow; we can form malic, oxalic, and formic acids, urea, &c.

Transformations of existing compounds are constantly taking place during the whole life of a plant, in consequence of which, and as the results of these transformations, there are produced gaseous matters which are excreted by the leaves and blossoms, solid excrements deposited in the bark, and fluid soluble substances which are eliminated by the roots. Substances containing a large proportion of carbon are excreted by the roots and absorbed

by the soil. Through the expulsion of these matters unfitted for nutrition, the soil receives again with usury the carbon which it had at first yielded to the young plants as food, in the form of carbonic acid.

The soluble matter thus acquired by the soil is still capable of decay and putrefaction, and by undergoing these processes furnishes renewed sources of nutrition to another generation of plants; it becomes *humus*.

Humus does not nourish plants by being taken up and assimilated in its unaltered state, but by presenting a slow and lasting source of carbonic acid, which is absorbed by the roots, and is the principal nutriment of young plants at a time when, being destitute of leaves, they are unable to extract food from the atmosphere.

Assimilation of Hydrogen. We can conceive of the formation of wood by the decomposition of water, its hydrogen uniting with the elements of carbonic acid, and oxygen being eliminated. 100 pts. carbonic acid unite with 8.04 hydrogen, to form woody fibre, and separate 72.35 oxygen, which was combined with the hydrogen.

From their generating caoutchouc, wax, fats, and volatile oils containing hydrogen in large quantity, and no oxygen, we may be certain that plants possess the property of decomposing water, because from no other body could they obtain the hydrogen of those matters. It has also been proved by the observations of Humboldt on the fungi, that water may be decomposed without the assimilation of hydrogen. Water is a remarkable combination of two elements, which have the power to separate themselves from one another, in innumerable processes, in a manner imperceptible to our senses; while carbonic acid, on the contrary, is only decomposable by violent chemical action.

All the hydrogen necessary for the formation of an organic compound is supplied to a plant by the decomposition of water. The process of assimilation, in its most simple form, consists in the extraction of hydrogen from water, and carbon from carbonic acid, in consequence of which, either all the oxygen of the water and carbonic acid is separated, as in the formation of caoutchouc, the volatile oils which contain no oxygen, and other similar substances, or only a part of it is exhaled.

The formation of acids is accompanied with the smallest separation of oxygen; the amount of oxygen set free increases with the production of the so-called neutral substances, and reaches its maximum in the formation of oils. Fruits remain acid in cold summers; while the most numerous trees under the tropics are those which produce oils, caoutchouc, and other substances containing very little oxygen.

Assimilation of Nitrogen. There is no reason for believing that the nitrogen, contained in all parts of a vegetable structure, is derived from that gas in its free state, for it cannot be made to unite directly with any element excepting oxygen. Ammonia, a compound of nitrogen and hydrogen, is one of the last products of the putrefaction or decay of animal matters.

It is capable of undergoing a multitude of transformations, in contact with other bodies, into the most various and opposite forms; either alone or with acids, it is very soluble in water; and hence it is probably the form in which nitrogen is conveyed to plants.

The thousands of millions of men and animals by death and decay yield a large quantity of ammonia, a portion of which must escape into the atmosphere; and the reason why it has not been previously detected is, that the quantity of air submitted to analysis is very small. Liebig proved its existence in pure rain-water by evaporation with muriatic acid; the sal ammoniac had always a brown or yellow color, with the offensive odor of perspiration or animal excrements, from which its origin might be inferred. It has since been found by many others in rain-water, snow, and hail. If we suppose 1 lb. of rain to contain $\frac{1}{4}$ grain of ammonia, then 26,910 square feet (1 Hessian acre) must receive annually 88 lbs. of ammonia or 71 lbs. of nitrogen, which is more of the latter (in the form of vegetable albumen and gluten) than is contained in 2920 lbs. wood, 3085 lbs. hay or 10 tons beet-root, (the produce of such an acre) but less than the grain, straw, and roots of grain, on the same surface.

Ammonia is evidently taken up by the roots of plants, and may be detected in many parts of their structure, in the juice of the maple tree, in the beet-root; it is obtained in the distillation of flowers, herbs, and roots, with water; the juice of the fresh tobacco leaf, of the vine contains ammonia.

The quantity of gluten (a nitrogenous body) contained in grain, seems to increase with the quantity of ammonia arising from manures. Thus, wheat grown in a soil manured with cow-dung (containing a little nitrogen) yielded only 11.95 per cent. gluten, while in a soil manured with human urine it afforded 35.1 per cent. Putrefied urine contains a large proportion of nitrogen in the form of ammoniacal salts. Guano yields also much ammonia, and hence a part of its fertilizing effects.

Gypsum (plaster) acts beneficially by fixing ammonia in the soil and preventing its evaporation; for the sulphate of lime and carbonate of ammonia mutually decompose into sulphate of ammonia and carbonate of lime. The use of burned clay as manure and the fertility of ferruginous soils depend on the fixation of ammonia by alumina and sesquioxide of iron, with which it forms chemical compounds. Powdered charcoal absorbs 90 times its volume of ammonia, decayed wood 72 times (See *Absorption*) and hence in part the use of humus.

The conclusion, then, is well established that the nitrogen of plants is derived from the ammonia of the atmosphere.

Inorganic Constituents of Plants. Plants absorb the soluble materials in a soil indiscriminately, retaining such as are necessary and returning the others as excrement. The various acids in plants are combined with potassa, soda, lime, and magnesia, which regulate their formation, and when the plants are incinerated, these salts remain as carbonates (see *Ashes*). And since certain acids are peculiar to plants

and essential to them, alkaline bases must be equally necessary. The capacity of saturation of these acids being uniform, the quantity of alkaline bases must be invariable.

Pine from Mont Breven,			
Carbonate of potassa	3.60	contains of oxygen	0.41
“ lime	46.34	“	7.33
“ magnesia	6.77	“	1.27
	56.71	Total oxygen	9.01

Fir from Alleverd,			
Potassa }	16.8	contains oxygen	3.42
Soda }			
Lime	29.5	“	8.20
Magnesia	3.2	“	1.20
	49.5	Total oxygen	12.82

The following analyses of ashes of 2 pine trees by De Saussure, and of 2 fir trees by Berthier, show that equivalent quantities of alkali are present.

from Mont La Salle.	
7.36 oxygen	0.85
51.19	8.10
00.00	
58.55	8.95

from Norway.	
14.1 oxygen	2.4
20.7	5.3
12.3	3.45
4.35	1.69
51.45 Total oxg.	12.84

The quantity of oxygen is too nearly the same in the bases of the pines, although the bases vary, to suppose it accidental; and in the fir trees, after deducting the oxygen of the bases which were combined with phosphoric, sulphuric, and chlorohydric acids, the remainders are 11.62 and 11.47 respectively. Hence the quantities of oxygen being the same, equivalent quantities of bases are saturated although these vary materially.

“If potatoes are grown where they are not supplied with earth, the magazine of inorganic bases (in cellars for example) a true alkali, called solanin, of very poisonous nature, is formed in the sprouts which extend towards the light, while not the smallest trace of such a substance can be discovered in the roots, herbs, blossoms, or fruits of potatoes grown in fields.

“The conclusion to which all the foregoing facts lead us is, that the alkaline bases existing in the ashes of plants must be necessary to their growth, since if this were not the case they would not be retained.

“The perfect development of a plant according to this view, is dependent on the presence of alkalies or alkaline earths; for when these substances are totally wanting, its growth will be arrested, and when they are only deficient, it must be impeded.”

10,000 parts of oak-wood yield 250 parts of ashes, the same quantity of fir-wood only 83, of linden-wood 500, of rye 440, and of the herb of the potato-plant 1500 parts.

Firs and pines find a sufficient quantity of alkalies in granitic and barren sandy soils in which oaks will not grow; and wheat thrives in soils favorable for the linden tree, because the bases which are necessary to bring it to complete maturity, exist there in sufficient quantity.

All kinds of grasses, the *equisetaceæ*, for example, contain in the outer parts of their leaves and stalk a large quantity of silicic acid and potash in the form of acid silicate of potash. The proportion of this salt does not vary perceptibly in the soil of corn-fields, because it is again conveyed to them as manure in the form of putrefying straw. But this is not the case in a meadow, and hence we never find a luxuriant crop of grass on sandy and calcareous

soils, which contain little potash, evidently because one of the constituents indispensable to the growth of the plants is wanting. Soils formed from basalt, grauwacke, and porphyry, are, *ceteris paribus*, the best for meadow-land, on account of the quantity of potash which enters into their composition. The potash abstracted by the plants is restored during the annual irrigation.

A harvest of grain is obtained every 30 or 40 years from the soil of the Lüneburg heath, by strewing it with the ashes of the heath-plants (*Erica vulgaris*) which grow on it. These plants during the long period just mentioned collect the potash and soda, which are conveyed to them by rain-water; and it is by means of these alkalies that oats, barley, and rye, to which they are indispensable, are enabled to grow on this sandy heath.

A proprietor of land in the vicinity of Göttingen, in order to obtain potash, planted his whole land with wormwood, the ashes of which are well known to contain a large proportion of the carbonate of that alkali. The consequence was, that he rendered his land quite incapable of bearing grain for many years, in consequence of having entirely deprived the soil of its potash.

The supposition that alkalies or inorganic matter in general are generated by plants is refuted by these facts. Steam and vapors have a remarkable power of transporting solid fixed matter, either in the form of a gas or dissolved in one.

It is known that in sea storms, leaves of plants in the direction of the wind are covered with crystals of salt, even at the distance of from 20 to 30 miles from the sea. But it does not require a storm to cause the volatilization of the salt, for the air hanging over the sea always contains enough of this substance to make a solution of nitrate of silver turbid, and every breeze must carry this away. Now, as thousands of tons of sea-water annually evaporate into the atmosphere, a corresponding quantity of the salts dissolved in it, viz.: of common salt, chloride of potassium, magnesia, and the remaining constituents of the sea-water, will be conveyed by the wind to the land.

By the continual evaporation of the sea, its

salts are spread over the whole surface of the earth; and being subsequently carried down by the rain, furnish to the vegetation those salts necessary to its existence. This is the origin of the salts found in the ashes of plants, in those cases where the soil could not have yielded them.

Art of Culture. Carbonic acid, ammonia, and water yield elements for all the organs of plants. Certain inorganic substances—salts and metallic oxides—serve peculiar functions in their organism, and many of them must be viewed as essential constituents of particular parts.

The atmosphere and the soil offer the same kind of nourishment to the leaves and roots. The former contains a comparatively inexhaustible supply of carbonic acid and ammonia; the latter, by means of its humus, generates constantly fresh carbonic acid, while, during the winter, rain and snow introduce into the soil a quantity of ammonia, sufficient for the development of the leaves and blossoms.

In whatever form we supply plants with those substances which are the products of their own action, in no instance do they appear to have any effect upon their growth, or to replace what they have lost. Sugar, gum, and starch, are not food for plants, and the same must be said of humic acid, which is so closely allied to them in composition.

The products generated by a plant may vary exceedingly, according to the substances given it as food. A superabundance of carbon in the state of carbonic acid conveyed through the roots of plants, without being accompanied by nitrogen, cannot be converted either into gluten, albumen, wood, or any other component part of an organ; but either it will be separated in the form of excrements, such as sugar, starch, oil, wax, resin, mannite, or gum, or those substances will be deposited in greater or less quantity in the wide cells and vessels.

The increase or diminution of the vital activity of the vegetables depends only on heat and solar light, which we have not arbitrarily at our disposal: all that we can do is to supply those substances which are adapted for assimilation by the power already present in the organs of the plant. But what then are these substances? They may easily be detected by the examination of a soil, which is always fertile in given cosmical and atmospheric conditions. Sand, clay, and lime are the names given to the principal constituents of the different kinds of soil. Pure sand and pure limestones, in which there are no other inorganic substances except siliceous earth, carbonate or silicate of lime, form absolutely barren soils. But argillaceous earths form always a part of fertile soils. There must, therefore, be something in aluminous earth which enables it to exercise an influence on the life of plants, and to assist in their development. The property on which this depends is that of its invariably containing potash and soda.

In order to form a distinct conception of the quantities of alkalies in aluminous minerals, it must be remembered that feldspar contains

17½ per cent. of potash, albite 11·43 per cent. of soda, and mica 3—5 per cent.; and that zeolite contains 13—16 per cent. of both alkalies taken together. The late analyses of *Ch. Gmelin, Löwe, Fricke, Meyer, and Redtenbacher*, have also shown, that basalt contains from ½ to 3 per cent. of potash, and from 5—7 per cent. of soda, that clay-slate contains from 2·75—3·31 per cent. of potash, and loam from 1½—4 per cent. of potash.

If, now, we calculate from these data, and from the specific weights of the different substances, how much potash must be contained in a layer of soil, which has been formed by the disintegration of 26,910 square feet (1 Hessian acre) of one of these rocks to the depth of 20 inches, we find that a soil of

Feldspar contains	.....	1,269,000 lbs
Clink-stone	“ from	220,400 to 440,000 “
Basalt	“ “	52,300 82,600 “
Clay-slate	“ “	110,000 220,400 “
Loam	“ “	95,800 330,600 “

Potash is present in all clays; according to *Fuchs*, it is contained even in marl; it has been found in all the argillaceous earths in which it has been sought.

Air, water, and the change of temperature prepare the different species of rocks for yielding to plants the alkalies which they contain. A soil which has been exposed for centuries to all the influences which affect the disintegration of rocks, but from which the alkalies have not been removed, will be able to afford the means of nourishment to those vegetables which require alkalies for their growth during many years; but it must gradually become exhausted, unless those alkalies which have been removed are again replaced; a period, therefore, will arrive when it will be necessary to expose it from time to time to a further disintegration, in order to obtain a new supply of soluble alkalies.

The exhaustion of much of the soil in Lower Virginia by successive crops of wheat and tobacco during a long period of time, proves the necessity of alkalies for these plants, for in the space of a century 13,200 lbs. of alkalies per acre were removed in leaves, grain, and straw, and the land became unproductive. When the soil is thus exhausted it requires the lapse of time for the action of air, water, change of temperature, and carbonic acid, to decompose fresh portions of the rocky constituents of the soil, and set free more alkaline matter.

Potash is not the only substance necessary for the existence of most plants; indeed it has been already shown that the potash may be replaced in many cases by soda, magnesia, or lime; but other substances besides alkalies are required to sustain the life of plants.

Phosphoric acid has been found in the ashes of all plants hitherto examined, and always in combination with alkalies or alkaline earths. Most seeds contain certain quantities of phosphates. In the seeds of different kinds of corn particularly, there is abundance of phosphate of magnesia.

Plants obtain their phosphoric acid from the soil. It is a constituent of all land capable of cultivation, and even the heath at Lüneburg

contains it in appreciable quantity. Phosphoric acid has been detected also in all mineral waters in which its presence has been tested; and in those in which it has not been found, it has not been sought for.

It is evident that the seeds of corn could not be formed without the phosphate of magnesia, which is one of their invariable constituents; the plant could not under such circumstances reach maturity.

Some plants, however, extract other matters from the soil besides silica, potash, and phosphoric acid, which are essential constituents of the plants ordinarily cultivated. These other matters, we must suppose, supply, in part at least, the place and perform the functions of the substances just named. We may thus regard common salt, sulphate of potash, nitre, chloride of potassium, and other matters, as necessary constituents of several plants.

Clay-slate contains generally small quantities of oxide of copper; and soils formed from micaceous schist contain some metallic fluorides. Now, small quantities of these substances also are absorbed into plants, although we cannot affirm that they are necessary to them.

De Saussure remarked that plants require unequal quantities of the component parts of soils in different stages of their development; an observation of much importance in considering the growth of plants. Thus, wheat yielded $\frac{7.0}{100.0}$ of ashes a month before blossoming, $\frac{5.4}{100.0}$ while in blossom, and $\frac{3.3}{100.0}$ after the ripening of the seeds. It is therefore evident that wheat, from the time of its flowering, restores a part of its organic constituents to the soil, although the phosphate of magnesia remains in the seeds. The fallow time, is that period of culture during which land is exposed to a progressive disintegration by means of the influence of the atmosphere, for the purpose of rendering a certain quantity of alkalies capable of being appropriated by plants. It is evident, that the careful tilling of fallow-land must increase and accelerate this disintegration. Now many plants in the family of the *leguminosæ* are remarkable on account of the small quantity of alkalies or salts in general which they contain. They belong to those which are termed fallow-crops, and the cause wherefore they do not exercise any injurious influence on corn which is cultivated immediately after them is, that they do not extract the alkalies of the soil, and only a very small quantity of phosphates.

Two plants growing beside each other will mutually injure one another, if they withdraw the same food from the soil. Hence it is not surprising that the wild chamomile (*Matricaria Chamomilla*) and Scotch broom (*Spartium Scoparium*) impede the growth of corn, when it is considered that both yield from 7 to 7.43 per cent. of ashes, which contain $\frac{9}{100}$ of carbonate of potash. Plants will, on the contrary, thrive beside each other, either when the substances necessary for their growth which they extract from the soil are of different kinds, or when they themselves are not both in the same stages of development at the same time.

On a soil, for example, which contains pot-

ash, both wheat and tobacco may be reared in succession, because the latter plant does not require phosphates, salts which are invariably present in wheat, but requires only alkalies, and food containing nitrogen.

According to the analysis of Posselt and Reimann, 10,000 parts of the leaves of the tobacco-plant contain 16 parts of phosphate of lime, 8.8 parts of silica, and no magnesia, whilst an equal quantity of wheat straw contains 47.3 parts, and the same quantity of the grain of wheat 99.45 parts of phosphates. (*De Saussure*.)

Now, if we suppose that the grain of wheat is equal to half the weight of its straw, then the quantity of phosphates extracted from a soil by the same weights of wheat and tobacco must be as 97.7 : 16. This difference is very considerable. The roots of tobacco, as well as those of wheat, extract the phosphates contained in the soil, but they restore them again, because they are not essentially necessary to the development of the plant.

Alternation of Crops. Experience has shown that the same crop cultivated on the same soil through successive years, deteriorates and will finally cease to yield profitably; that certain plants will thrive better after others, and that these last will then again become productive.

The experiments of Macaire-Princep prove that substances are excreted from the roots of plants, some of which he termed acrid and resinous, others mild like gum. The former he regarded as injurious, the latter nutritious. Hence the opinion that the same plant will not thrive in a soil where its excretions accumulate.

Decandolle supposes that plants absorb soluble matter of every kind from the soil, and thus receiving much matter unnecessary for nutrition, return it as excrement to the soil.

The excretion consists of two parts, that which is returned to the soil in an unaltered state and that arising from transformations which have taken place within the plant. The former, although useless to a particular plant, may be nutritive to another. The latter appears to change into humus by a more or less gradual change, and then yielding carbonic acid, forms the nutriment of young plants.

This artificial production of humus constitutes one advantage of the alternation of crops, and such plants are employed as excrete abundantly.

Another advantage lies in the different kinds of inorganic matter required by different plants. Thus two plants requiring the same, and grown successively on the same ground, gradually renders it incapable of producing them profitably; but where one follows another requiring different inorganic constituents, the decomposing action of atmospheric agents during the lapse of time prepares the soil again for the production of the first.

Manure. We may regard organic and many inorganic substances as manures; but we find them varying much in their value both practically and by an analysis of their constituents. Thus the solid excrements of the cow and horse contain but little nitrogen, human fæces more; urine contains a large proportion. But the excrements of animals con-

tain much silicate of potassa and phosphates, human fæces the latter, while urine is rich both in nitrogenous matter and phosphates. Too much cannot be said on the employment of human excrements both liquid and solid, for while they constitute fertilizing manure of the highest value, they are usually rejected in the United States. (See MANURE.)

We have presented an outline of the newer views in agricultural chemistry, chiefly due to Liebig, whose essay we have followed and freely extracted from, not, however, from a conviction of their truth in every respect; for we believe that, although he has adopted a true method in elevating agriculture and physiology by the application of chemical principles, he has by no means proved that carbonic acid, water, and ammonia constitute the sole nourishment of plants. We therefore offer the opinions of others likewise grounded on experimental evidence.

NUTRIMENT FROM ORGANIC AND INORGANIC MATTER.

Saunders has conducted some very able experiments which seem to prove that some plants do take up humus, not in the form of carbonic acid. He showed, contrary to the experiments of Hartig, that humus extracted from mould by alkali is absorbed by the roots; and that since a strongly coloured solution of humate of potassa becomes discolored in the *Polygonum Persicaria*, while other coloring matters, such as ink, unfitted for nutrition, are not—that this humic material is assimilated. Without denying that carbonic acid and water are assimilated as nutritive matter, he holds humic extract is likewise useful to plants; that plants produced by the former alone are not as thrifty as with the use of mould. The following are his general conclusions.

1. That fertile soil contains a mixture of soluble and insoluble organic matter; and that the introduction of the former by the roots into a plant is a powerful aid to that nutrition which is afforded by the atmosphere and water.

2. That the insoluble organic, greatly preponderating over the soluble, undergoes, by the assistance of water, slow fermentation, hence producing soluble nutritive matter.

3. That plants receive their nitrogen almost entirely by absorption of soluble organic matter.

4. That those colored substances adapted to the nutrition of plants change color, while those not nutritious enter a plant without undergoing decomposition. (*Biblioth. Univers.*)

Hermann has discovered that the chief part of the extractive matter in the juice of plants consists of similar constituents to humus, containing humic acids, several crenic and apocrenic acids, and extractive humus. (See HUMUS.)

Mulder's experiments lead to the conclusion that, by the decay of vegetable substances, ulmin and ulmic acid are formed when the air is not freely admitted, and these again, by the action of the air, pass into humin and humic acid. His analyses of the humic acid in turf, decayed wood, and vegetable mould from various localities, prove that it is combined with ammonia, and the remarkable re-

semblance in the deduced formulæ, seems to prove conclusively that there is a class of humus bodies, which, although differing among each other, must be ranked together.

Mulder supposed this ammonia to have been abstracted as such from the air, but Hermann's experiments prove that during the decay of wood 1 volume of nitrogen and 2 vols. of oxygen are absorbed from the air, and 4 vols. carbonic acid given off, and that ammonia is a residual transformation.

These researches of Saussure, Mulder, and Hermann are certainly opposed to the views of Professor Liebig, and we may add to them the elaborate researches and conclusions of Boussingault and Payen. The following is the definition of powerful manures by the two last-named chemists:—Manure is the more valuable in proportion as the quantity of nitrogenous organic matter is greater than the non-nitrogenous organic matter; and in proportion as the decomposition of quaternary compounds acts gradually, and agrees with the progress of vegetation. They have therefore constructed a table showing the value of manures, that is, the quantity of nitrogen they contain. See MANURE.

Boussingault holds that plants receive a large proportion of nutriment from the air, but also receive no inconsiderable amount of organic material directly from the soil. He believes that the process of fallowing has chiefly the advantage of destroying weeds; that the system of rotation of crops does not depend on the injurious action of the excrements of plants, since Braconnot's experiments prove that such excrements are not produced, but it rather depends on the alternation of such plants as only extract nutrition from the soil, like the Gramineæ, and of such as take much nutriment from the air, like the Leguminosæ, and whose stubble ploughed under is in itself a good manure.

In conclusion, we may remark that Liebig has shown that a large proportion of the organic matter of plants is due to the assimilation of carbon from carbonic acid, but not that it is wholly due to this cause. He has not shown that their nitrogen is obtained from the ammonia of the atmosphere, while the formation of ammonia in humus seems to point out this combination as the source of the nitrogen, a view strengthened by the experiments and inferences of Boussingault and Payen. Whether we adopt with the former the view that nitrogen is the measure of nutrition, we hold with him that the nitrogenous compounds in the soil are partly useful because of the more ready decomposition of compounds containing nitrogen, so that the carbon and hydrogen of such substances are more readily assimilated.

Again, Liebig censures the application of the principles of animal nutrition to vegetable physiology, and yet more than once draws such a comparison himself. It may be wrong to apply these principles in the same manner in both cases, but the principles themselves may hold good of both. Thus, while he has shown the importance of one constituent of the air, carbonic acid, another acts an equally important part to animals; for, without the action of the oxygen in producing internal

transformations and throwing off carbon, food cannot be regarded as nutriment. The oxygen of the air therefore serves in part for the nutrition of animals. While thus plants derive much nutrition from the air and a portion from the soil, animals derive much from the soil and a portion from the air. See farther under DE-CAY, EXCREMENT, GUANO, HUMUS, MANURE, PUTREFACTION, SOIL. See *Johnson's Farmers' Encyclopædia*, Am. edition.

AIR. *Chem.* A term applied to gaseous bodies in the early days of chemical science, from their resemblance to atmospheric air. Ammoniacal gas was called *alkaline air*, nitrogen *mephitic* and *phlogistic air*, oxygen *dephlogisticated air*. Carbonic acid is still, but rarely, termed *fixed air*. See ATMOSPHERIC AIR.

AKMITE. *Min.* Syn. Achmite, Acmite. *Phys. Cryst.* Oblique rhombic system, nearly the same as augite (*Mitscherlich*); cleaves

parallel to M, less perfectly parallel to the diagonals. $H=5.5-6.5$. Spec. grav. 3.2—3.5. Brown or reddish-brown; lustre vitreous; opaque, when thin translucent, and yellowish-brown; streak pale yellowish-gray; fracture uneven, earthy; brittle.

Chem. behavior. In a bulb yields water, leaving a spot which disappears on heating; easily fused on charcoal to a shining, black, magnetic bead; dissolves in borax and mic. salt to a glass colored by iron, leaving a skeleton of silica in the latter; with soda gives on charcoal a black glass; on platinum foil the green of manganese.

When finely powdered is imperfectly decomposed, both before and after fusion, by sulphuric and chlorohydric acids.

Analysis. By Ström. and Berzelius, *K. Vet. Ac. Handl.* 1821, p. 160, and *Jahresber.* xi. 94; and by Lehunt, *Thoms. Outlines*, i. 480.

	Ström.	Berz.	Leh.
Silica	54.27	55.25	52.016
Alumina	—	—	0.685
Peroxide of iron	34.44	31.25	FeO=28.080
Oxide of manganese		1.08	MnO= 3.487
Soda	9.74	10.40	13.333
Lime	—	0.72	0.876
Magnesia	—	—	0.504
Loss by ignition	1.88	—	—
	100.33	98.70	98.981

V. Kobell found in it 3.25 per cent. titanac acid, of which Berz. found only traces, and showed that part of the iron was protoxide. The formula appears to be $\text{NaO}, \text{SiO}_3 + \text{Fe}_2\text{O}_3$, 2SiO_3 (neutral silicate of soda + $\frac{2}{3}$ persilicate of iron), but G. Rose gives it $3(\text{NaO}, \text{SiO}_3) + 2(3\text{FeO}, 2\text{SiO}_3)$ from its affinities with hornblende.

Locality. Only at Rundemyr, 4 m. N. of Dunserud, near Kongsberg, Southern Norway, in granite, in crystals sometimes a foot long, macted and bent, and so brittle as not to be easily detached.

ALABANDINE. *Min.* See MANGANESE GLANCE.

ALABASTER. *Tech.* A white, translucent stone of moderate hardness, usually sculptured into delicate ornaments, such as lamps, vases, clock-frames, &c., which are much valued from their pure whiteness, their permitting the light to pass faintly through them, and the delicate polish of their surface.

There are 2 varieties of alabaster: the *gypseous*, which is more generally used and preferred, is a fine-grained and compact sulphate of lime; the *calcareous* is a crystalline carbonate of lime. The former is therefore softer than the latter, and both are softer and more easily wrought than marble.

The fine-grained, harder, and snowy gypsum of Volterra, near Florence, is preferred to most others, and from its uniformity and freedom from defects, is wrought into ornaments of considerable size. It is also wrought at Salzburg, in Austria, in Spain, Derbyshire, England, &c. The calcareous A. is more employed in the East, and being derived from stalactites, often presents zones of yellow, brown, and red hues, which impart a higher value to

it. The travertine of San Filippo, in Tuscany, is employed in a similar manner; it is a mixed carbonate and sulphate of lime, &c., and is still depositing in such quantities, that basso-relievos are made by exposing sulphur moulds to the water, which in the course of a few months incrusts them with a deposit of considerable thickness.

Alabaster is sawed into suitable blocks, then worked with the knife and chisel either in the open hand or the turning-lathe. Being used merely to abrade the surface gradually, the tools should not be too sharp. For delicate ornaments, small files and graving tools are employed. The harder or calcareous variety is worked much in the same way as marble.

The gypseous A. is smoothed with dried shave-grass or horse-tail (*Equisetum*), the hardness of which is due to its large content of silica, and the streaks left by this are removed by rubbing the surface with a paste of finely-sifted slaked lime and water. The delicate polish is given by a mixture of soap-water and lime, and lastly by elutriated French chalk or talc. Small pieces are cemented together by powdered quick-lime and white of egg, or by a stiff paste of boiled plaster and water.

Ornaments of A. are liable to a yellow tarnish from the action of smoke, &c., which may be often removed by washing with a little soap-water. Grease spots are removed by a rubbing with powdered French chalk or spirit of turpentine. Much water should not be used, since it etches the surface.

A. may be etched by taking advantage of the solubility of gypsum in water. Cover the parts not to be etched by a varnish of wax dissolved in turpentine and thickened with white-lead, and when it has set, immerse the objects

ALALITE.

in water for one or two days, according to the depth of the etching required. Remove the varnish by spirit of turpentine, and to give the etching a degree of opacity contrasting well with the rest, rub it with a brush dipped in powdered gypsum.

Calcareous A. is etched in a similar manner, by adding to the water a little muriatic or acetic acid.

A. may be coloured by metallic solutions, or by solutions of vegetable colors in oil or alcohol. This, however, should be rarely attempted, for its delicate snowy whiteness is one of its principal attractions.

ALALITE. *Min.* See AUGITE, var. *Diopside*.

ALBIN. *Min.* See APOPHYLLITE.

ALBITE. *Min.* Syn. Cleavelandite, Tetartin, Tetarto-prismatic feldspar, Pericline.

ALBUMEN.

Crystal. Triclinometric, or doubly oblique rhombic, $P : M = 93^\circ 50'$; $P : T = 115^\circ 5'$, $M : T = 117^\circ 53'$. Generally in flat, twin crystals, with M enlarged, the re-entering angle of $P : P' = 186^\circ 40'$. Where imperfectly developed, the cryst. structure is foliated, passing into granular. Cleavage perfect parallel with M and P , less so with T .

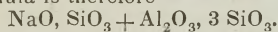
$H = 6-6.5$. Spec. grav. 2.6—2.68. Albite from Chester co., Pa., and from Newcastle co., Del., had a spec. grav. of 2.612 (*Booth and Boyé*). Color white, more rarely bluish, grayish, greenish, or reddish-white; lustre pearly on planes of the perfect cleavage, otherwise vitreous; transparent to opaque; fracture uneven, somewhat brittle.

Behavior. Behaves like feldspar before the blowpipe, but colors the flame yellow. Insoluble in acids.

Analysis.

	Finbo by Vauquelin.	Sweden by Eggertz.	Freiburg by Brandes.	Finnland by Tengström.	Arendal by G. Rose.	Chesterfield by Stromeyer.	Massachusetts by Laurent and Holmes.
Silica.....	70	70.48	69.8	67.99	68.46	70.676	68.4
Alumina.....	22	18.45	18.2	19.61	19.30	19.801	20.8
Peroxide of iron....	—	—	—	0.70	0.28	0.111	0.1
Lime.....	—	0.55	0.6	0.66	0.68	0.235	0.2
Soda.....	8	10.50	10.0	11.12	9.12	9.056	10.5
	100	99.98	98.6	100.08	97.84	99.879	100.0

All these analyses show that albite is a soda-feldspar, a neutral silicate of alumina and soda. The formula is therefore



A portion of the soda is generally replaced by potassa, lime, &c., as in common feldspar there is also soda, lime, &c. The calculated composition of albite is

4 eq. silica.....	185.04	59.09
1 " alumina.....	51.47	19.22
1 " soda.....	31.32	11.69
	267.83	100.00

Pericline was separated from albite, as an analysis of a compact specimen by C. Gmelin seemed to require it, but Thaulow's analysis of a crystallised specimen shows that it is identical with albite. We have examined 2 specimens of albite, one highly crystalline from the vicinity of Wilmington, Del., and another crystalline and granular from Chester county, Pa., both apparently pure. Redtenbacher examined one from Pennsylvania, which was possibly the same as ours from Chester county.

	Gmelin.	Thaulow	Redtenb.	B. & B. Chester Co.	B. & B. Wilmington.	Abich.
Silica.....	67.94	96.0	67.20	67.72	65.46	70.22
Alumina.....	18.93	19.43	19.64	20.54	20.74	17.29
Peroxide of iron.....	FeO=48	—	—	trace	0.54	0.82
Magnesia.....	Loss=36	—	0.31	0.34	0.74	0.41
Lime.....	.15	0.20	1.44	0.78	0.71	2.09
Soda.....	9.99	11.47	9.91	10.65	9.98	5.62
Potassa.....	2.41	—	1.57	0.16	1.80	3.71
	100.26	100.10	100.07	100.19	99.97	100.16

Our last analysis differs so much from the others that we would be inclined to suppose it a different mineral, for it appeared to be pure, and yet the oxygen in the silica is nearly $2\frac{1}{2}$ that in the bases. See Gmelin and Thaulow in *Rammelsberg's Mineralogy*; Redtenbacher in *Pogg. An.* xi. 470; Booth and Boyé in *Proc. of Am. Phil. Soc.*, May, 1841, and June, 1842.

V. Kobell thinks that Beudant's Adinole is a dense albitic mass mingled with quartz.

Remarks.—Albite often replaces feldspar in granite, syenite, &c., and Abich has shown that the mass of the trachyte in the Drachenfels, insoluble in acids, is albite in which much of the soda is replaced by lime (see above).

At Chesterfield, Mass., it occurs in lamellar masses, the laminae often radiating, and is associated there with green and red tourmaline. In Delaware it is associated with common feldspar, and may be easily distinguished from it by its more pearly lustre. It is in general distinguished from common feldspar by its superior whiteness, its more pearly lustre, and its marked yellow flame before the blowpipe.

ALBUMEN. *Ger.* Eiweissstoff. This substance, which derives its name from the Latin for the white of an egg (*album ovi*), in which it exists most abundantly and in its purest natural state, is one of the chief constituents of many of the animal solids and fluids. Besides

in the white of egg, it abounds in the serum of blood, the vitreous humor of the eye, and in all serous secretions. Combined with different fatty matters and water, it constitutes the yolk of egg, the brain, the spinal marrow, and the nerves, and also several of the viscera and glands (the liver). A similar substance, *vegetable albumen*, in every respect identical with *animal albumen*, occurs in the seeds of all gramineous plants, principally the cereals, and in those of papilionaceous plants, such as peas and beans, in all of which it occurs combined with starch and vegetable gluten; also in those seeds which by pounding with water form an emulsion, such as almonds, the seeds of the castor-oil plant (*Ricinus communis*), and of hemp (*Cannabis sativa*), where it exists combined with oil. It occurs further in all vegetable saps and juices that coagulate by heat.

The chief characteristic of albumen is its coagulability by the action of heat. We, therefore, speak of it in its two conditions, *soluble* or *uncoagulated albumen*, and *insoluble* or *coagulated albumen*. The difference between the white of an egg before and after it is boiled will give the best idea of these two different conditions.

Animal Albumen. a. *Soluble* or *Uncoagulated*. It may be obtained in the solid form by evaporating at a temperature that does not exceed 120° the clear serum of blood or white of egg till it forms a dry, transparent mass, of a yellowish color, and brittle. This is powdered and treated successively with ether and alcohol, which extract fat, salts, and other foreign matters, and leave the albumen pure. When thus completely dry, it forms a white or faintly yellowish powder, without taste or odor, and without either acid or alkaline reaction. It may in this state be heated even to 212° without passing into the insoluble or coagulated condition. Moistened with water it swells up, becomes transparent, and dissolves by the addition of more water into a colorless fluid which is perfectly tasteless. When this solution is heated to 140° it becomes turbid, and when sufficiently concentrated soon congeals by the passage of the albumen into its insoluble or coagulated state. Less concentrated solutions of albumen, and particularly if they contain free alkali, do not coagulate unless heated to between 158° and 167°, and very dilute solutions require even boiling for their coagulation and clearing. A solution containing $\frac{1}{10}$ of dry albumen forms by heat a solid coagulum. A content of $\frac{1}{15}$ gives a glairy liquid, but a solution containing $\frac{1}{1000}$ part will still become opalescent by heat. Alcohol precipitates albumen from its solution, but if not concentrated or used in too great excess, the albumen redissolves again in water, though otherwise it passes into its coagulated state. Ether shaken with serum has no other effect on it than to extract fat, but the albumen in the white of egg is coagulated by it; it absorbs the ether and floats on top of the solution. Oil of turpentine and fixed oils do not dissolve albumen. Albumen combines in its uncoagulated state with *acids* and *bases*, but these combinations have not been studied much, on account of the facility with which acids cause it to pass into its coagulated state. If white of eggs be mixed

with water and during continued stirring sulphuric acid added drop by drop till the solution has an acid reaction, the tissue in whose cells the albumen was contained precipitates, and may be separated by filtration. The clear solution of *sulphate of uncoagulated albumen* may then be evaporated in vacuo over sulphuric acid to dryness, forming a transparent mass of a pale lemon color, soluble again for the greater part in water, from which it may be precipitated by heat as *sulphate of coagul. alb.*, which is insoluble in water. A similar result may be produced by alcohol; and sulphuric, chlorohydric, and even acetic acids added to the solution, cause in the same way the sulphate of coagul. alb. to precipitate. The presence of *alkalis*, when in small quantity, does not transform the albumen into its coagulated form. Thus, most of the animal fluids, notwithstanding their alkaline reaction, contain it in its uncoagulated state. A portion of this alkali is probably in combination with albumen, forming an *albuminate*, while the other portion is present as carbonate. Several metallic oxides, as oxide of copper, and the oxides of iron, when mixed with serum or the white of eggs in their fresh precipitated state, dissolve in it, and color subsequently the coagulum when precipitated by heat. Albumen is coagulated by several organic bodies, as tannic acid and kreasote, which latter acts catalytically, as a small quantity suffices to coagulate a large quantity of albumen without entering into combination with it. Rennet has no effect on albumen. Soluble albumen when once transformed into its insoluble or coagulated state, cannot again be reduced to its former condition; in the chemical processes of animal life it is always found in its uncoagulated state.

b. *Insoluble* or *Coagulated Albumen* is obtained by heating serum or white of eggs to between 160° and 170°, triturating the solidified mass in a mortar with water, and then washing it successively with cold water, alcohol, and ether. Thus prepared, it retains a portion of phosphate of lime, from which it may be obtained free by the following process. The albuminous liquid is mixed with dilute chlorohydric acid, which precipitates chlorohydrate (muriate) of coagul. albumen. This is freed from the mother-liquid by washing with very dilute chlorohydric acid; it is then mixed with a sufficient quantity of pure water to dissolve it. The solution of chlorohydrate (muriate) of albumen is then decomposed by carbonate of ammonia, which precipitates the albumen as a white flocculent precipitate, which is again washed with water and dried, and finally freed completely from fat by boiling alcohol. When dried in pieces it forms a yellowish transparent mass, resembling, in most of its chemical characters, fibrine. (See FIBRINE.) After coagulation it may be kept for a long time under water without suffering change; but when exposed in a moist state to the atmosphere, it rapidly passes into a state of putrefaction. It does not, however, generate oxygen from the deutoxide of hydrogen. By destructive distillation it yields combustible gases, empyreumatic oil, and ammoniacal water, which contains sulphuret of ammonium. There remains a

porous coal, which, when obtained from albumen that has not been treated with chlorohydric acid, is incinerated with difficulty, leaving an ash consisting of phosphate of lime with a trace of magnesia. This quantity of ashes amounts to from 1.8 to 2 p. c. and over, but is in some cases stated to amount even to 8 or 9 p. c.; so that albumen seems to combine under different circumstances with different proportions of phosphate. Coag. and dried albumen swells up in water and assumes its former appearance, but remains insoluble in water. Chevreul found that 1000 p. of water only dissolved 7 p. of albumen, when in this state. By continued boiling with water it suffers a decomposition. Mulder found that, by 40 hours boiling, water dissolved 37 parts out of 100 albumen. What dissolved did not possess any of the properties of albumen, nor did it gelatinize, or in other respects resemble glue. Coag. alb. is also insoluble in alcohol, ether, volatile and fixed oils.

It combines with *acids*. If coagulated albumen be treated in its moist state with a dilute acid, it dissolves; but an excess of acid precipitates again the combination. Sulphuric, nitric, metaphosphoric, and chlorohydric acids, therefore precipitate albumen in its coagulated state, when added to a solution of it in excess; but the precipitate with sulphuric acid is insoluble in pure water, which by continued washing extracts most of the acid. The other hydrates of phosphoric acid, carbonic, and acetic acids dissolve the alb. even when present in excess. From all these solutions in acids the albumen is precipitated by the addition of an alkaline carbonate till the exact neutralization of the acid. The solution in acetic acid loses the acetic acid by evaporation, and leaves behind coagulated albumen. By digestion, nitric acid converts albumen with generation of nitrogen into a yellow pulverulent substance, named by Mulder xanthoproteic acid (which see). Concentrated chlorohydric acid in the proportion of 7 or 8 parts to 1, dissolves coag. alb. with a deep blue color. By dilution with water chlorohydrate of albumen precipitates, but the solution retains its color, which, however, disappears by subsequent neutralization with ammonia. Yellow ferroproussiate of potassa precipitates albumen with the addition of an acid, or when added alone to its soluble compounds with acids. The precipitate is a combination of albumen with cyanohydric acid and cyanide of iron, which is insoluble in an excess of acid, but dissolves in alkali.

Dilute solutions of the *alkalis* as well as barytic, strontian, and lime-water, dissolve coag. alb. in its moist state, forming perfectly neutral albuminates. These combinations may then be concentrated, and evaporated to dryness in vacuo over sulphuric acid, or precipitated by addition of alcohol. The albuminate of potassa and soda is insoluble in alcohol and also in a concentrated solution of caustic potassa, by which the fact has been explained, that serum of blood or white of egg deposits a coagulum on both anodes by the passage of a galvanic current through it, chlorohydrate of alb. depositing on the anode, where there is an excess of free chlorohydric acid; and albu-

minate of soda on the kathode, where there is an excess of free alkali. Although albumen combines without change with the alkalies when dilute and at ordinary temperatures, the presence of these in excess, or the application of heat, converts the albumen into protein (see *PROTEIN*), which remains in the solution combined with the alkali, and may either be precipitated by the addition of an acid, or still further decomposed by the action of alkali and heat, and converted into leucin, protid, and erythroprotid (see these), and several other products; while its phosphorus and a portion of its sulphur combine with the oxygen from the decomposition of a portion of the alkali, whose metallic radical combines with another portion of its sulphur, and thus gives rise to the formation of phosphate, sulphite, and sulphuret of the alkali. Albumen forms insoluble compounds with the earths and the metallic oxides, which may be obtained by precipitating a saturated solution of alb. in potassa or ammonia with their respective salts. The albuminates of the colored oxides have generally the usual color of their salts; they dissolve in caustic potassa or soda, forming basic double salts.

The reaction of albumen with *salts* is highly interesting. Coagulated albumen dissolves in its moist state in concentrated solutions of the salts of the alkaline bases, and expels a portion of the carbonic acid when boiled with solutions of their carbonates. For phosphate of lime it exhibits great affinity, and forms not only a soluble compound, which occurs in serum and the white of egg, but also an insoluble compound with a much larger proportion of the phosphate. Uncoagulated albumen yields with the salts of the earths and the metallic oxides precipitates, which consist of compounds of albumen, with both the acid and the base, from which the combination with the acid may be removed by washing with water, leaving the albuminate of the oxide behind. If their acetates be employed for the precipitation of albumen from animal fluids, acetate of albumen remains in solution, and the precipitate consists of an albuminate of the metallic oxide. In all these cases the albumen passes into its coagulated state. Alum in powder coagulates albumen and forms a solid mass, which property has been made use of in medicine for external applications. A solution of neutral acetate of lead precipitates both serum and albumen from white of egg, but a great portion of the albumen remains in solution as acetate of albumen. Basic acetate of lead, on the contrary, precipitates it completely; the precipitate contains besides the albuminate of lead, sulphate, phosphate, and basic chloride of lead. Uncoagulated albumen precipitates a solution of chloride of mercury completely. The precipitate consists here, as in other precipitations of metallic salts, of muriate of albumen, and an albuminate of the oxide of mercury, of which the former may be completely removed by washing with cold water. If a solution of albumen be precipitated by a solution of chloride of mercury in excess, the muriate of albumen generally becomes insoluble and is precipitated. But if solutions of albumen and chloride of mercury

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be mixed in such proportions as to decompose each other completely, or if the albumen predominates, most of the muriate of albumen remains in solution. This explains fully the action of albumen as an antidote for corrosive sublimate, since it shows that the chloride of mercury is decomposed by it. Cyanide of mercury yields no precipitate with uncoagulated albumen. Albumen of the brain, yolk of egg, &c., vide **BRAIN**, **EGG**, etc. The globules of blood and the crystalline lens of the eye contain a substance, which much resembles albumen, but differs from it in some respects. See **GLOBULIN**.

The following has been found to be the composition of pure albumen :

	By exper.	Atoms.	By calc.
Carbon.....	54.84	400	54.70
Hydrogen....	7.09	310	6.92
Nitrogen.....	15.83	50	15.84
Oxygen.....	31.23	120	21.47
Phosphorus..	0.33	$\frac{1}{2}$	0.35
Sulphur.....	0.68	2	0.72

Mulder, who first discovered the presence of phosphorus in its unoxidized state, considers albumen as a compound of 10 atoms of an organic substance, which he terms protein (see **PROTEIN**), with a sulphuret of phosphorus P_4S_2 , $10(C_{40}H_{31}N_5O_{12}) + P_4S_2$. Berzelius, however, suggests that, if we consider protein as an oxide of a compound radical, albumen might contain the sulphur and phosphorus combined with this same radical, so as to consist of a certain number of atoms of an oxide (protein), with 1 atom of the phosphuret and 2 atoms of the sulphuret of the same radical. Mulder has pointed out a difference in the composition of albumen from white of egg and from serum of blood. If white of egg be coagulated by heat without previous neutralization of its free alkali by acetic acid, sulphuret of sodium will be found in the solution, while the coagulum only contains 1 atom of sulphur to every $\frac{1}{2}$ atom of phosphorus, but after previous neutralization of the alkali the albumen obtained by coagulation from the white of egg, has the same composition as that obtained from serum, whether this be previously neutralized or not.

Albumen is the true starting-point from which all animal tissues are formed, as the egg contains no other nitrogenized compound except albumen, the yolk containing only, besides albumen, a yellow fat. All nitrogenized food, whether of animal or vegetable origin, is first converted into soluble albumen, before it can be used for nutrition. (*Liebig*.) Albumen itself is therefore highly nutritious, and constitutes an important part of all animal food. When either raw or lightly boiled, it is easy of digestion; but when boiled hard, or especially when fried, its capability of being digested is considerably impaired. Its use as an antidote against poisoning by corrosive sublimate has already been mentioned. *Peschier* states that one egg is required for every 4 grains of the poison. It is also an antidote for preparations of copper (blue vitriol and verdigris), and for bichloride of tin.

Techn. From its coagulability, albumen is of

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great use in clarifying liquids (see **CLARIFICATION**). It is likewise remarkable for the property of rendering leather supple, for which purpose a solution of white of eggs in water is used by leather-dressers. Bookbinders make use of glaire as a varnish.

Vegetable albumen possesses nearly all the characters of animal albumen. Before its coagulation it is soluble in water; it does not stick, and assumes, on drying, either a white, gray, or black color. It dissolves in caustic alkali, and may again be precipitated by addition of an acid in excess. It precipitates then in combination with the acid, insoluble in an excess of acid, but soluble in water, which solution yields a precipitate with ferropotassiate of potassa, chloride of mercury, and an infusion of gallnuts. In the moist state it enters rapidly into putrefaction, with the same odor as animal substances, and yielding like these ammoniacal products. a. *Veget. alb. in green plants.* If green plants and fresh shoots of trees be crushed and pressed, a green liquid is obtained, having the smell of grass, which passes turbid through the filter, and settles with great difficulty to a clear liquid. By heating it to 140° or 160° it coagulates, and may then be filtered. The coagulum consists of vegetable albumen, in combination with a green wax-like fat, which may be extracted by alcohol, or, still better, by ether. A portion of it, however, always remains, and imparts to the albumen a faint green color. On drying, the albumen becomes black. It possesses all the characteristic properties of albumen: some woody fibres generally remain on dissolving it in caustic potassa. If the green liquid be coagulated by an acid, the green color is converted into a gray. The pressed plants still contain, after treatment with water and alcohol, coagulated albumen, which may be extracted by dilute caustic potassa and precipitated by the addition of an acid. The juice of roots, such as potatoes, beets, &c., deposit also, when heated, a coagulum of a caseous albumen, resembling, in its relation, that of emulsive seeds. b. *Veg. alb. of emulsive seeds.* Many seeds, such as almonds, &c., form, by being pounded up with water, a milk or emulsion, which contains, in suspension, numerous globules, of a size so small as to pass through paper. But such vegetable milk differs from animal milk, by being coagulated by heat, whereby albumen precipitates with an oil, which may be removed by pressing, and subsequent treatment with alcohol or ether. The remaining albumen is white, and becomes transparent and brittle on drying. After coagulation by heat, still more albumen may be obtained by evaporation and precipitation by alcohol. c. *Veget. alb. in wheat, rye, barley, Indian corn, &c.* See **GLUTEN**.

Vegetable albumen has lately been shown to be perfectly identical in composition with animal albumen. Mulder had, however, previously shown the identity of the protein contained in them both.

Use. On the importance of vegetable albumen in bread and other vegetable food, see **GLUTEN**. The albumen in green plants forms an important part of the nourishment of herbivorous animals.

ALBUMINATE. *Chem.* A compound of albumen, with a base.

ALBUMININ (*Oonin*). The albumen in the white of egg is enclosed in cells from which it flows when they are torn by trituration. Couerbe obtained this substance by exposing white of egg to a temperature from 32° to 18° for several months. It forms a white, membranous substance, which is characterized by the absence of nitrogen in its composition. When dry, it forms a white, transparent, and brittle mass, which, when heated, is decomposed without fusion, and yields no ammoniacal products. It is insoluble in cold and boiling water; in the latter it swells up to a mucilaginous mass. It is insoluble in alcohol, ether, and acetic acid. Sulphuric and nitric acids decompose it. Chlorohydric acid dissolves it, and by dilution with water causes a white pulverulent precipitate. It is likewise soluble in caustic potassa; by the addition of an acid a turbidness but no precipitate is produced. To distinguish it from albumen, Couerbe named it albuminin or oonin. It deserves a closer study.

ALCARAZZAS. *Tech.* Porous vessels of burned clay, of a bulging form, with a narrow neck, designed to cool wines and water by evaporation from their surface. The liquid constantly and slowly percolating through the body of the ware to the outer surface, evaporates in the warm climates where the vessels are used, particularly in a slight current of air, so that a considerable amount of heat is carried off in the vapor. Under favorable circumstances, the temperature may be lowered 50° below that of the atmosphere, when the latter is 75° to 90°.

Porous vessels for the same purpose are in use in China, Persia, India, Egypt, &c., and were undoubtedly introduced into Spain by the Moors, as shown by their name. The best are made at Anduxar, in Andalusia, from a suitable clay or marl on the small stream Pamusoro, and have a yellowish red color. Similar jugs of a grayish white color are made at Salvatierra, in Estremadura, and called Buccaros. In Egypt they are rather high-dried than burned over a straw-fire. They are farther manufactured in England, and to a limited extent in the United States.

ALCHEMY. *Syn.* Alchymia, Archymia (?). The words alchemy and chemistry were originally one and the same, but the term chemistry is now applied to the science as it exists and has existed for more than a century, while alchemistry is applied to it previous to its establishment as a true science, when it was rather an art, and that chiefly the art of making gold. It is not difficult to understand how the manifold and often complicated changes in metallurgic operations by the influence of heat on chemical affinity could have originated the belief that gold could be produced from ignoble metals, when by simply heating a purple powder (the precipitate of Cassius, see under **GOLD**), the noble metal, gold, appeared; when by a mixture of copper and zinc ores without any metallic appearance, a golden-yellow metal (brass) could be procured, which might easily deceive the eye.

The origin of alchemy is involved in mystery, as indeed its earliest writings are also clothed with mystery. Many works were issued from Alexandria in the 5th and 6th centuries, and the art passed over to the Saracens, &c., who wrote numerous works on it during several centuries, even as late as the 13th. Dshafar or Geber (in 9th century, at Seville) is an excellent writer, with more true knowledge than all the chemists for six centuries after him, although he gave credit to the art of making gold, and taught that all metals consisted of 3 elements.

The art entered western Europe partly through the Saracens, and partly from fugitive Greeks, beginning about the 13th century, and gradually spreading through the following centuries, until it reached its crisis in the 17th. To the true believers in the mutation of metals were latterly added many who designed to deceive, and the art became a pestilence, spreading through whole communities, and embracing rich and poor, king and peasant, ignorant and learned.

Edward III. protected Raimond Lully, Henry VI. of England gave patents for making gold; the Emperor Rudolph II., of Germany, established an alchemistic academy at Prague about 1600. King Augustus II., of Saxony, caught the adept Böttger, who had fled from Berlin, and confined him in a castle, giving him every means of transmuting metals; and it was here that he conceived the first ideas from his experiments of making porcelain. See **PORCELAIN**.

The learned were also given to alchemy. Tycho de Brahe endeavored through it to obtain means for pursuing astronomy. Their object was not the pursuit of science, but the practical application of experiments to the arts, pharmacy or alchemy, the last prevailing over all others. Albertus Magnus, Roger Bacon, Raimond Lully, Basil Valentine, Paracelsus, Libavius, Beecher, Kunckel, Glauber, and many other eminent men, were devoted to these pursuits, and it is impossible to draw the line between the true chemists and alchemists of those times. But the accumulation of facts through the unwearied labors of alchemists, and their classification, gradually paved the way for the advancement of true science, so that the more learned and sensible philosophers of the 18th century withdrew from the ranks of alchemy; but among the unlearned we find traces of belief in the art to this day. Thus chemistry rose on the ruins of alchemy.

The principal objects of the alchemists were two preparations:—1. A red, solid body, the philosopher's stone, the grand elixir, magisterium, the red tincture, which, when dropped in exceedingly minute quantities on liquid silver, mercury, lead, or any base metal, changed it perfectly into gold when well prepared, or only partially if not well prepared. 2. The same preparation, administered internally in infinitesimal doses, healed many diseases, restored youth to age, lengthened life, and was hence termed the elixir or panacea of life. 3. Another preparation, a white solid, the stone of the 2d order, the small elixir, magistery, the white tincture, which was the first preparation

half-advanced to perfection, and changed base metals into silver.

It is impossible to say what the philosopher's stone was, or how it was prepared, for no one has given an account of it; but chemistry teaches us that their processes were the results of error, illusion, and deception. Thus, one of these transmuting powders was sulphuret of sodium, containing gold, and when metallic silver was thrown into it while in fusion, sulphuret of silver was necessarily produced, and metallic gold precipitated, which was thought to be generated. Sometimes silver was gilded, or a preparation of gold amalgamated with mercury, so that by heat the mercury evaporated and left pure gold. All their processes are of such a stamp, and never was the metal gold wanting in their preparations, so that from its fixed nature it must remain when subjected to heat.

The belief has not yet passed away that gold was made; for, say such persons, a belief held for 14 centuries could not be wholly error,—the metals are not yet shown positively to be elements, and therefore their transmutation is not impossible, and many who were not deceivers have borne witness to transmutation. It should, however, be remembered that many errors have outlived centuries, such as the quadrature of the circle, which is older than alchemy, and has many adherents to this day. It is true that we have not proved the elementary nature of the metals, and indeed there is rather a probability that they are not so, from the chemical and physical similarity of many of them, and from the small number of their compounds in comparison with the endless numbers of those comprised in organic nature, consisting only of 4 elements, carbon, hydrogen, oxygen, and nitrogen. But the crude operations of the alchemists could not have produced a mutation, supposing it possible, and we have far more powerful and a far greater number of means of decomposition than they had, without attaining such a result. Lastly, although we must give credit to many learned men for an implicit and honest belief in alchemy, yet we attribute to them error in observation or deduction, particularly as we can trace these errors in their processes.

In conclusion, then, we must believe that gold has never been made, but we cannot say positively that it never will be, for organic chemistry reveals to us wonderful transformations; but we may say, from all the knowledge we possess, that it is not at all probable that it ever will be. Notwithstanding the loss of time, health, life, and the wasting of much intellectual power by the alchemists during the lapse of ages, yet they have bequeathed us a valuable legacy in the numerous facts which were used as the foundation of chemistry as a science, and, without the search for the philosopher's stone, chemistry would long have toiled ere it had attained its present elevated position of utility to mankind. (*Handwört. d. Chemie, art. Alchemie.*)

ALCOATE. Alcohol behaves towards many salts like water, forming crystalline compounds with several of them, when they separate from their solutions in it. Thus, if fused chloride

of calcium be dissolved by heat in alcohol and exposed to cold, it separates in three sided striated plates, which are a combination of chloride of calcium with alcohol ($\text{CaCl} + 2\text{C}_4\text{H}_6\text{O}_2$). Such compounds are called *alcoates*, and correspond with *hydrates*, but are much less stable: thus the above crystals of *alcoat* of chloride of calcium enter into fusion by 86° and lose all their alcohol by 204° . The *alcoates* of the *nitrates* of lime and *magnesia*, and of the *chlorides* of *manganese* and *zinc* behave similarly.

ALCOHOL. *Chem.* This term is applied to the pure spirit obtainable by distillation from all liquids that have undergone vinous fermentation.

We distinguish between absolute alcohol and alcohol of commerce, or spirits of wine, which is abs. alcohol mixed with different proportions of water.

Absolute Alcohol. Prep. Alcohol of commerce is frequently shaken for several days in a closed vessel, with an equal weight of fused and coarsely powdered chloride of calcium (muriate of lime). It is then poured off into a retort, and half of its volume distilled over. The very first portion contains generally some water, and is put aside; the rest is pure alcohol, and has a spec. grav. of 0.7947 at 59° , or 0.791 at 65° F. If the spec. grav. be greater, the same process is once more repeated.

Instead of chloride of calcium unslacked lime may be employed. The retort is filled to $\frac{2}{3}$ of its bulk with fresh quicklime in small pieces, and the alcohol then added so as to cover the lime. This attracts the water with such avidity as often to cause the liquid to become hot. After a digestion over the lime, of 2 to 3 hours or more, the alcohol is distilled over slowly by the heat of a water-bath. If the alcohol employed be too weak, repetition of the process is necessary. This method yields a product applicable for most technical purposes; but it often contains traces of lime, from which it may be freed by redistillation. Caustic potassa cannot be used with safety for obtaining anhydrous or absolute alcohol, as it is apt to alter it, especially when in contact with the atmosphere.

By mere distillation, alcohol cannot be freed from water beyond a certain point (10 to 15 per cent.). The above substances act by their great affinity for water, abstracting and retaining it so as to allow the pure alcohol to be distilled off. Other substances are often employed for the same purpose, but are less effective, such as carbonate of potassa, which abstracts most of the water, and forms with it a dense solution, below and separate from the alcohol; but alcohol cannot be obtained perfectly anhydrous by distillation over this substance, even when employed in its freshly ignited state, or by repetition of the distillation. Effloresced or calcined sulphate and carbonate of soda, plaster of Paris, calcined clay, &c., are not capable of freeing it more effectually from water than can be done by careful distillation alone.

Other methods have been devised for obtaining absolute alcohol, but they are of more interest in a scientific than in a practical point

of view. Thus, if moderately strong alcohol be enclosed in an ox or calf's bladder or any other animal membrane, and suspended over a sand-bath or in any other warm place, the inside of the bladder will absorb the water and allow it to evaporate on the outside. Soemmering, who first discovered this, advises to cover the inside of the bladder with a coating of isinglass, and states that it may thus be obtained absolute, but the process is slow, and the alcohol always dissolves some fatty matter, from which it can only be freed by distillation. Another method of procuring small portions of absolute alcohol is to place a shallow vessel containing spirits of wine in an exhausted receiver over unslacked lime. The receiver soon becomes filled with the vapors of alcohol and water, the latter of which is alone absorbed by the lime, its place being supplied by a renewed evaporation of the water from the alcohol till it is perfectly anhydrous.

Prop. Pure anhydrous or absolute alcohol is a colorless liquid, of greater fluidity than water, having a faint but agreeable odour, and a sharp burning taste, which diminishes considerably by addition of water. Its caustic taste is due to the great avidity with which it attracts water from all living tissues with which it is brought in contact, destroying their vitality; it may therefore cause death, when introduced into the stomach. But these poisonous effects cease when diluted. Taken in small quantities, it produces hilarity; in greater, intoxication. The spec. grav. of absolute alcohol is, 0.7947 at 59°; 0.792 at 64°; 0.791 at 68°, and 0.739 at its boiling point. Its spec. heat is 0.52. It is a nonconductor of electricity and shows no signs of decomposition by the passage of an electrical current through it. Alcohol has never been frozen. Dr. J. K. Mitchell, of Philadelphia, who by evaporation of solid carbonic acid and ether in vacuo, has produced the greatest cold ever attained, found that alcohol of spec. grav. 0.798 became oily and adhesive at -130°; by a greater cold it became still thicker, and at -146 it flowed like melted wax. Alcohol of 0.820, froze easily.

Alcohol does not expand uniformly by heat; the greatest uniformity of expansion is between -14 and +98, amounting to 0.00047 of its volume for every degree. Gay-Lussac examined the contraction of alcohol from the temperature of its boiling point, or 173°, and constructed the following table, giving the contraction of the alcohol for every 9° in 1000th parts of its volume at the boiling point.

Temperature Fahrenheit.	Volume of alcohol.	Temperature Fahrenheit.	Volume of alcohol.
173.....	1000.0	101.....	954.3
164.....	994.4	92.....	949.1
155.....	988.6	83.....	944.0
146.....	982.5	74.....	939.0
137.....	975.7	65.....	934.0
128.....	970.8	56.....	929.3
119.....	965.3	47.....	924.5
110.....	969.7	38.....	919.9

Alcohol boils at 173° at a barometric pressure of 29.5 inches. 1 vol. of alcohol yields

488.3 vol. of alcoholic vapor measured at 212° compared with water, it yields a larger volume of vapor by 3.14 times. The spec. grav. of the vapor is 1.613. If alcoholic vapor be passed through a red hot tube, it is decomposed and yields aldehyde, light carburetted hydrogen, and water; at higher temperatures it deposits carbon and yields a mixture of combustible gases. Alcoholic vapor mixed with three times its vol. oxygen and ignited by an electrical spark explodes with violence, and yields double its vol. carbonic acid, and three times its vol. of vapor of water. Alcohol itself is highly combustible, and burns with a whitish, slightly smoking flame, which deposits carbon on cold bodies held in it. Mixed with water, it burns with a flame entirely blue, and deposits no carbon. If alcohol be burned by a wick, surrounded by a spiral of platinum wire, and the flame then be suddenly blown out, the platinum wire continues to incandesce, caused by the imperfect combustion of the alcoholic vapors, giving rise to the formation of lactic acid (see this, and *Aldehydic acid* under *ACETYLE*), of a pungent and disagreeable smell (Aphlogistic or Davy's lamp). Platinum black (finely divided platinum), moistened with a small quantity of alcohol becomes incandescent, but if moistened with a larger quantity, so as to prevent the rise of the temperature but still to leave both the alcohol and platinum in contact with the atmosphere, oxygen is absorbed and the alcohol converted into acetic acid and acetic ether, aldehyde and acetal (see these). By a continued action of the platinum, the two latter are also converted into acetic acid.

At ordinary temperatures, alcohol suffers no change by contact with the atmosphere. From moist air it absorbs water, and dissolves likewise some air, which may be easily expelled by heat, without alteration. Its power to dissolve oxygen is about 2½ times greater than that of water. According to Saussure, it dissolves 0.1625 of its own volume of oxygen. By admixture of water a portion of this oxygen is expelled, in small bubbles, and gives rise to a kind of passing turbidness or effervescence. Nitrogen is dissolved in about equal quantities by them both.

The affinity of alcohol to water is very strong, and heat is generated by their mixture. If, on the contrary, alcohol be mixed with snow or pulverized ice, it produces cold. Absolute alcohol, cooled down to 32° Fah. and mixed with a somewhat larger quantity of snow than it is capable of melting, will cause a fall of the temperature to -35°. Spirits of wine of 0.86 sp. gr. and 61° temperature, mixed with snow of 32°, is cooled down to -14°. By the mixture of alcohol with water, a contraction takes place, which increases regularly, till the mixture consists of 1 at. alc. to 3 at. water, or 100 pts. alcohol and 116.23 water. 100 vol. of this mixture contain, at 59°, 53.94 vol. of anhydrous alcohol, and 49.84 vol. of water, which, therefore, have contracted from 103.78 to 100. The spec. gravity of this mixture is 0.927 at 59°. From this point, the contraction, by new additions of water, diminishes until by a certain dilution, an apparent expansion takes place. Thus, Thillaye found that 3 vol. of

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dilute alcohol of 0.954 spec. grav. and 7 parts of water yielded a mixture of 0.9850 spec. grav. instead of 0.9863, showing an increase in vol. of 0.0013. In this case heat is generated, notwithstanding this expansion, which latter merely is apparent and depends on a diminution of its previous contraction. If the mixture be made of anhydrous alcohol and water, till it acquires the above spec. grav. of 0.985, there will be found an actual diminution of volume of 0.007. The following table shows the contraction for every decrease of 5 per cent. in the content of alcohol:

Pr. ct. in vol. of abs. alcohol in 100 vol. of the mixture at 59°.	Contraction of volume in per ct. of the mixture.	Pr. ct. in vol. of abs. alcohol in 100 vol. of the mixture at 59°.	Contraction of volume in per ct. of the mixture.
100	0	50	3.745
95	1.18	45	3.64
90	1.94	40	3.44
85	2.47	35	3.14
80	2.87	30	2.72
75	3.19	25	2.24
70	3.44	20	1.72
65	3.615	15	1.20
60	3.73	10	0.72
55	3.77	5	0.31

It may be seen from this table that the same diminution of volume may occur by the mixture of very different proportions of alcohol and water (3.44 for 70 and 40 per cent. alc.). The avidity with which absolute alcohol attracts water from the atmosphere, renders it necessary to keep it in well-stoppered bottles, in order to preserve it anhydrous.

As the spec. grav. and expansion of alcohol is altered by the addition of water, so the admixture of this fluid likewise affects its volatility in an interesting manner. Tralles found that the admixture of a minute quantity of water did not raise the boiling-point; and Soemmering has shown, that alcohol containing two to three per cent. of water is even more volatile than absolute alcohol. Alcohol, of 94 per cent., or of a spec. grav. of 0.82 at 59°, has exactly the same volatility as abs. alcohol, and if alcohol of 0.8 spec. grav. be subjected to distillation, the portion that first distills over contains the greatest quantity of water, while the alcohol becomes stronger during the distillation, till finally, the last portion that distills over is anhydrous. If, on the contrary, alcohol that contains more than 6 per cent. of water be subjected to distillation, the portion that distills over is always stronger in alcohol than the portion remaining in the retort, and the temperature at which this boils rises continually, so that its strength might be ascertained by the temperature of its vapors, indicated by a thermometer immersed in the upper part of the retort. Groening has attempted to apply this practically, and constructed the following table, in which the first column indicates the temperature; the second the per centage of alcohol in the boiling liquid; and the third, the content of alcohol in the vapor, or the condensing distillate. (See table in next column.)

The reaction between alcohol and other substances differs according to its greater or less

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Temperature.	Per cent. of alcohol in the boiling liquid in retort.	Per cent. of alcohol of the distillate.
171	92	93
158.9	90	92
172	85	91.5
172.7	80	90.5
173.8	75	90
175.1	70	89
176	65	87
178.3	50	85
180.5	40	82
182.8	35	80
185	30	78
187.3	25	76
189.5	20	71
191.8	18	68
194	15	66
196.3	12	61
198.5	10	55
200.8	7	50
203	5	42
205.3	3	36
207.5	2	28
209.8	1	13
212	0	0

dilution with water. In general, its peculiar reactions and properties are diminished in proportion to its dilution.

Alcohol dissolves *sulphur*. When saturated by heat, the solution deposits, on cooling, sulphur, in small transparent crystals. The solution becomes turbid by addition of water, and possesses a disagreeable hepatic odor. If alcohol and sulphur be brought together, as vapors for instance, by suspending a vessel with alcohol in a vessel in which sulphur is sublimed, a red colored solution is obtained, which contains a compound of sulphur, formed by the decomposition of the alcohol, and which, like sulphuretted hydrogen, precipitates metallic solutions. Alcohol likewise dissolves *phosphorus*. According to Buchner, phosphorus requires 320 parts of cold and 240 parts of boiling alcohol, of which latter solution one-fourth of the phosphorus separates again, on cooling. The saturated solution phosphoresces in the dark. *Chlorine* is absorbed by alcohol, and decomposes it. See *CHLORAL* and *CHLOROFORM*. If the alcohol contain water, several other products are formed. See *ALDEHYDE*, &c. The action of bromine is similar. See *BROMAL*. *Iodine* dissolves in alcohol, with a brown color. When dissolved by heat, it deposits on cooling in crystals. The solution contains, after some time, iodohydric acid, and assumes an ethereal smell. Alcohol has no action on charcoal, but it mixes in all proportions with sulphuretted carbon, and is then decomposed by the addition of caustic alkali. See *XANTHOGEN*.

Anhydrous alcohol is decomposed by *potassium* and *sodium* with the liberation of hydrogen gas. See *ETHER*. It dissolves the *hydrates of potassa and soda*, forming, at first, a clear solution, which soon becomes brown, by the decomposition of alcohol and the formation of a resinous matter, which may be precipitated by the addition of an acid. The *hydrates of lithio, baryta, strontia, and lime*, are insoluble in alcohol. *Ammoniacal gas* is absorbed by it in great

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quantity. The *earths* and the *metallic oxides* are insoluble in it. The *alkaline sulphurets* dissolve readily in alcohol.

The stronger *acids*, in general, act on alcohol, and give rise to the formation of ether. See ETHER. Those which contain a larger amount of oxygen and readily part with it, such as strong nitric and chloric acids, decompose it still farther.

Most of the gases are absorbed by alcohol, and several of them in a larger proportion than by water, as shown by the following table of Saussure's:

There is absorbed at 64° of	By 1 volume air-free water.	By 1 vol. air free alcohol, sp. gr. 0.84
Sulphurous acid gas	43.78 vols.	115.77 vols.
Sulphuret. hydrogen	2.53	6.06
Carbonic acid.....	1.06	1.86
Nitrous oxide.....	0.76	1.53
Olefiant gas.....	0.155	1.27
Oxygen	0.065	0.1625
Carbonic oxide....	0.062	0.145
Hydrogen	0.046	0.051
Nitrogen	0.042	0.042

Alcohol also absorbs 68 vols. chlorohydric acid gas, a considerable amount of nitric oxide, and 23 vols. cyanogen.

The solubility of the different salts in alcohol will be found under them. All salts of inorganic acids which are insol. or sparingly sol. in water, are, in general, also insol. in alcohol; and also effervescent salts. The deliquescent salts, on the contrary, are generally soluble in alcohol, excepting carb. potassa. Most of the chlorides which are readily soluble in water, dissolve also in alcohol; and some, such as chloride of mercury, are even more soluble in alcohol than in water. The organic acids, and most of the salts of the fatty acids, dissolve also in alcohol. With some salts, it combines chemically. See ALCOATE. Its power of dissolving substances sol. in water, increases, in general, with its content of water; but for resins and fats, vol. and fixed oils, and other substances for which it is a specific solvent, this power decreases strongly by the addition of water.

Th. de Saussure was the first who ascertained with any accuracy the composition of alcohol, since which it has been analyzed, with corresponding results, by Duflos, Dumas, and Boullay, and others. It consists of

	Atoms.	In 100.
Carbon.....	2 or 4	52.650
Hydrogen	3 or 6	12.896
Oxygen	1 or 2	34.454

The vapor of alcohol consists of—

2 vols. of carbon vapor (.8429 × 2)	= 1.6858
6 " hydrogen.... (.0688 × 6)	= 0.4128
1 " oxygen..... (1.1026 × 1)	= 1.1026

Condensed to 2 vol. alcohol vapor..... 3.2012
Of which one volume weighs..... 1.6006

Gay-Lussac found by actual experiment, the spec. gravity of its vapor to be 1.6133.

In reference to the manner in which these

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elements are arranged, there exists some diversity of opinion. Saussure, and after him Dumas and others, considered it as the bihydrate of carburetted hydrogen, composed of—

4 vol. of carburetted hydrogen (etherin)	(0.9804 × 4) = 3.9216
4 vol. of vapor of water (0.6201 × 4) =	2.4804

Condensed to 4 vol. of vapor of alcohol 6.4020
Of which one vol. weighs..... 1.6005

But alcohol is now generally considered as the hydrate of ether, or oxide of ethule (see ETHER), consisting in 100 parts of

1 atom of the oxide of ethule.....	80.624
1 atom of water	19.376

or, in its gaseous state, of

$\frac{1}{2}$ volume of vapor of ether.....	1.2906
$\frac{1}{2}$ " " water.....	.3101

Combined to 1 vol. of vapor of alcohol. 1.6007

Its formula is then $C_4H_5O + HO$, and its atomic weight 46.52 ($H = 1$), or 580.62 ($O = 100$).

Berzelius, however, considers alcohol as the oxide of a separate radical (C_2H_3), and expresses its composition by the formula $C_2H_3 + O$. Its atomic weight becomes then only half of the former, or 23.26 ($H = 1$), or 290.31, ($O = 100$). The reasons on which he founds his supposition are: 1. If alcohol really were a hydrate and moreover the hydrate of a base, (the oxide of ethule,) it ought to be possible to abstract its water by other bases, which have a stronger affinity for water. The affinity for water of baryta, for example, is so great that it will bear ignition without parting with it, still it is not capable of separating any water from alcohol or liberating ether. 2. When a basic body combines with water to a hydrate, this hydrate is a salt-like compound, in which the water performs the part of an acid, but having less power of neutralization, the bases retain more of their original properties. The very reverse is the case with ether, or the oxide of ethule. It combines with acids to neutral compounds, most of which retain the character of the ether to a remarkable degree, while this is not the case with alcohol. Water would therefore produce a greater change in the character of ether than the acids, by combining with it. 3. Alcohol of 0.927 spec. grav., that is, that hydrate of the oxide of ethule in which the elements have suffered the greatest contraction, would consist of 1 at. of oxide of ethule and 7 at. of water, which relative number is less probable. 4. Ether dissolves water, and water ether, but they may again be separated by distillation without the formation of any alcohol (see 1st reason). 5. Analogy with wood spirit, or methylic alcohol and methylic ether, or oxide of methule, (see METHULE), two substances which bear the same relation to each other as alcohol and oxide of ethule. Methylic alcohol combines with anhydrous baryta to a crystalline compound, which, when heated, first gives off a portion of the methylic alcohol unaltered; and, when the remaining compound is still further heated, the methylic alcohol suffers the destructive decomposition

rather than be separated into water and oxide of methule.

The main support for the theory of alcohol being the hydrate of the oxide of ethule is derived from the fact, that when the oxide of ethule is separated from any of its neutral compounds with the acids, by the hydrate of an alkali, it always appears as alcohol; which would afford a striking analogy with other bases, which, under similar circumstances, always separate as hydrates. Again, by the reaction of potassium with anhyd. alcohol, the latter gives off half of its oxygen to the potassium, while the equivalent hydrogen is liberated, and the ether thus formed combines with the potassa to a crystallisable compound, which may be removed, and from which, by the addition of water, it is again separated as alcohol; it therefore agrees well with the usual reaction of potassium with hydrates, and is rather in favor of this theory. For the theoretic view of the formation of alcohol from sugar, see FERMENTATION.

2. In commercial and pharmaceutical language, the names of alcohol and spirit of wine are applied to mixtures of absolute alcohol, or alcohol properly so called, with different proportions of water, obtained by purification and rectification of ardent spirits or liquors, such as brandy, rum, gin, whisky, arrack, &c. (see these). The ardent spirits or liquors are mixtures of alcohol (54 per cent. or less) with a greater proportion of water and volatile oil (oil of grain, &c.), and are themselves obtained by distillation from vinous liquids, or such as have undergone the vinous fermentation, by which alcohol is produced in liquids containing sugar or substances convertible into it. (See FERMENTATION.)

Spirit of wine and commercial alcohol have a spec. grav. of from 0.900 to 0.825 and contain from 64 to 92 per cent. of absolute alcohol. *Alcohol* of U. S. Pharmacopœia, or *rectified spirit*, Lond. Pharm., has a spec. grav. of 0.835, and contains 89 per cent. by volume, or 85 per cent. by weight, of absolute alcohol. This, diluted with its equal volume of water, forms the *diluted alcohol* of U. S. Pharmacopœia, which has a spec. grav. of 0.935, and contains 49 per cent. by vol., or 42 per cent. by weight, of absolute alcohol, and corresponds nearest in strength to what, in commerce, is called proof spirits, but is actually a pure diluted alcohol, while the commercial proof spirits contain volatile and empyreumatic oil, and often coloring matters, such as burned sugar, together with aromatic tinctures, designed to impart a peculiar flavor.

Commercial alcohol is prepared from ardent spirits or distilled liquors (see these), which consist of alcohol, water, and volatile oil (oil of grain, or potato spirit oil, fousel oil, &c.). Of these, the alcohol is so much more volatile than the water that it can be separated to the desired strength by simple distillation, but the volatile oil—particularly that of grain—follows it very pertinaciously, and can only be removed by the addition of a substance that combines with it, and thereby renders it less volatile. The best method is to perform the distillation over a sufficient quantity of well charred and coarsely

powdered coal of pine, fir, birch, or other porous wood. The still is filled with $\frac{1}{6}$ or $\frac{1}{4}$ of the volume of the liquor, and the first $\frac{1}{6}$ or $\frac{1}{4}$ of the distillate collected separately. Should this not prove sufficiently free from it, the distillation is repeated over a new smaller portion of the charcoal. The oil may also be removed previously to distillation by filtration through coarsely powdered charcoal (birch, &c.), for which purpose a filter constructed on the plan of Dumont's (see FILTRATION) may be employed with advantage, and will remain effectual for a longer time. If the brandy contain empyreumatic oil, this can only be removed by digestion with animal charcoal in a close vessel and subsequent filtration.

The action of charcoal is very striking, for to free 25 galls. of strong liquor from fousel oil, 6—10 lbs. charcoal are requisite, but the same coal may be used for twice that quantity. There is, however, a difference between the different kinds of charcoal. Lüdersdorff's experiments in the following table show this clearly. A quart of spirit of 80 per cent. Tralles was purified.

Potato Spirit by	Oz.
Fir-wood charcoal.....	1
Linden ".....	$\frac{5}{8}$
Birch ".....	$1\frac{1}{4}$
Willow ".....	2
Oak ".....	$2\frac{1}{4}$
Bone black.....	5
Grain Spirit by	Oz.
Fir-wood charcoal.....	$1\frac{3}{8}$
Birch ".....	$1\frac{7}{8}$
Linden ".....	$1\frac{1}{2}$
Willow ".....	$2\frac{1}{2}$
Oak ".....	4
Bone black.....	7

Small portions of chloride of lime have also been employed for the removal of the oil, which is decomposed by it, and remains behind by the distillation, but the chloride of lime is apt to react on the alcohol, the products of which follow the alcohol in the subsequent distillation. An addition of milk before the distillation has also been recommended, but the coagulated milk is apt to adhere to the bottom of the still and become scorched by the heat. The removal of the oil has also been attempted by shaking the brandy with fixed oils. Garbel recommends as a very effectual remedy, to mix the brandy, previous to the distillation, with so much caustic potassa as to give it a faint alkaline reaction. By distillation, the oil then is retained in combination with the potassa.

The distillation itself is performed in an ordinary still with its capital and worm, but in order to obtain a strong alcohol several repeated distillations are requisite. See DISTILLATION.

A very important improvement has been introduced into modern distilleries, by which a concentrated alcohol may be procured by a single distillation from fermented wort, wines, and other weak spirituous liquids. It depends on the fact noticed in a table above given, that the boiling point of alcohol is higher in proportion to its content of aqueous vapor, or in

other words, the temperature at which alcoholic vapors condense is lower when the content of water is smaller, and in direct proportion until we approach absolute alcohol. Thus, if we pass the vapors of dilute alcohol, such as wine, &c., through a series of vessels like a Woulfe's apparatus, a large proportion of water will condense in the first with a little alcohol, for the vessel becoming heated, say to 200°, the vapor of spec. grav. 0.928 has this boiling or condensing point, and contains 53 per cent. alcohol by vol., while the balance, now richer in alcohol, has a lower condensing point and passes to the second vessel; the second becoming heated also, but to a lower point, say 187°, another strength of alcohol condenses, viz. that which has such a boiling point and a spec. grav. of 0.8765, and contains 75 per cent.; in the third vessel, at a temperature of 177°, it will condense with a spec. grav. of 0.8458 and contain 86 per cent. It was in fact by such an arrangement of Woulfe's bottles that the process was discovered in Montpellier, France, of obtaining a strong alcohol by a single distillation. A variety of stills have since been constructed on this principle, of which Pistorius's, in Germany, has been celebrated for its convenience and economy of fuel.

The still given in Pl. II. figs. 5, 6, and 7, patented in 1830, in England, is a good form for this process. It consists of the kettle for the liquid to be distilled, the rectifier, a series of cooling boxes placed above the kettle, and the neck and worm for condensing the strong alcoholic vapor. The vapor rising in the spacious capital enters the first partition of the water-condenser, where it is slightly cooled by contact with the hollow vessel *i.* fig. 5. This vessel is convex above, flat beneath, and has a rim around its edge to detain the vapor for a moment. The cold water flowing over the boxes, passes through these vessels, and hence refrigeration is greatly promoted. The first box may represent the first Woulfe's bottle above mentioned, where a dilute alcohol condenses, since from its proximity to the kettle, its temperature must be high. Whatever condenses must flow back into the kettle from the very form of the still. Rising through the second and third boxes, more aqueous vapor with portions of alcohol are condensed and flow back, until the vapor which reaches the top of the capital and passes into the neck is a strong alcohol of nearly 90 per cent. See farther under *STILL*.

The advantages of such modern stills lie in economy of fuel, time, and labor; in diminished liability to boiling over, or explosion; and generally in greater freedom from essential oil, a portion of which condenses with the water and returns to the kettle.

Uses. Alcohol meets with an extended application in the arts, chemistry, and pharmacy, depending on its solvent power, generally different from that of water, from its combustibility, and its effects on the animal economy. 1. As a *solvent*. It is largely used for dissolving resinous substances, which are incapable of solution in water; and these solutions are termed spirit varnishes. See *VARNISHES*. A solution of essential oils, in alcohol, consti-

tute many of the scented waters of the perfumer, such as Cologne and Lavender waters, &c., for which purpose, either the essential oils, or the parts of plants from which they are derived, are treated with strong or dilute alcohol. See *ESSENCES*. Alcohol is farther used by the pharmacist in the preparation of various tinctures, resinous extracts, spirits, ethers, &c. See *TINCTURES*.

It is farther employed in some manufacturing operations, such as in the preparation of the vegetable alkalies, ethers, pure potassa, &c. The chemist frequently avails himself of its solvent power in his analytic researches, especially in organic chemistry, since it dissolves volatile oils and fats, resin, extractive, sugars, veget. alkalies, urea, leucin, gliadin, picromel, &c.; and even in inorganic research it is often a convenient reagent, as in the separation of sulphate of lime from sulphate of magnesia. See these several articles.

2. As a *fuel*. In nice chemical operations, alcohol is much employed in lamps, being preferred to oil on account of its cleanliness, and the freedom of its flame from smoke. For the same reasons it is sometimes, but rarely, employed in domestic economy. See *LAMP*.

3. Independently of its pharmaceutical use, as a solvent, &c., it is also used *medicinally*, both internally and externally. For internal administration, as a stimulant and excitant; externally, as a styptic, to restrain hemorrhage, from its coagulating the blood (see *ALBUMEN*), and at the same time causing contraction of the bleeding parts, as a wash in various cutaneous diseases, and as a cold lotion. In case of poisoning by spirituous liquors, the most effectual remedy after evacuation of the stomach is a solution of acetate of ammonia.

4. Alcohol is farther useful as an *antiseptic*. It prevents the putrefaction of animal and vegetable substances, and is therefore extensively employed in the preservation of anatomical preparations. It seems mostly to act by binding the water, the free action of which is necessary to all chemical changes, such as putrefaction, fermentation, &c. For this purpose it is best to begin with a weak alcohol (50 per cent.) and change it several times for a somewhat stronger. Stronger alcohol preserves better than a weaker, but in the same proportion it is apt to destroy the natural colors, and alter or harden the tissues.

ALCOHOLOMETRY is the process of estimating the quantity of absolute alcohol in an alcoholic liquid, for commercial as well as other purposes. It is always done by ascertaining the spec. grav. of the liquid, but it is then necessary that it should contain nothing but alcohol and water, or at least not in such quantity as to affect its specific gravity. The content of alcohol in spirits, which contain a large amount of volatile oil or sugar, or other substances dissolved in them, cannot, therefore, be estimated directly by their spec. grav.

In order to be able to calculate the content of absolute alcohol in an alcoholic liquid from its spec. grav., it was found necessary to mix absolute alcohol and water in the different proportions, and by actual experiment ascertain the spec. grav. of these mixtures. Such ex-

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periments have been undertaken at different times. The most accurate and complete are those performed by Gilpin, and published in the *L. and E. Phil. Trans.*, 1794. From these and additional experiments Tralles constructed, in 1811, the tables given below.

The percentage of absolute alcohol in any spirituous liquid may be given either by weight or by volume. As liquors are sold by measure, not by weight, it is generally preferred to know the percentage by volume. The volume of absolute alcohol is then always given as

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measured at a normal temperature, which, in the following tables of Tralles, is 60°.

The per cent. by weight remains the same at all temperatures, but the per cent. by vol. varies with the temperature of the liquid.

The following table of Tralles exhibits the percent. of abs. alcoh. by vol. measured at a temp. of 60° Fahr., which is contained in an alcoholic liquid, the spec. grav. of which has also been ascertained at 60°, taking water at the temp. of its greatest density as 1, and therefore having at 60° a spec. grav. of 0.9991.

TABLE I.

Per cent. of Alcohol by volume.	Spec. grav. of the liquid at 60°.	Difference of the spec. gravs.	Per cent. of Alcohol by volume.	Spec. grav. of the liquid at 60°.	Difference of the spec. gravs.
0	0.9991		51	0.9315	20
1	9976	15	52	9295	20
2	9961	15	53	9275	20
3	9947	14	54	9254	21
4	9933	14	55	9234	20
5	9919	14	56	9213	21
6	9906	13	57	9192	21
7	9893	13	58	9170	22
8	9881	12	59	9148	22
9	9869	12	60	9126	22
10	9857	12	61	9104	22
11	9845	12	62	9082	22
12	9834	11	63	9059	23
13	9823	11	64	9036	23
14	9812	11	65	9013	23
15	9802	10	66	8989	24
16	9791	11	67	8965	24
17	9781	10	68	8941	24
18	9771	10	69	8917	24
19	9761	10	70	8892	25
20	9751	10	71	8867	25
21	9741	10	72	8842	25
22	9731	10	73	8817	25
23	9720	11	74	8791	26
24	9710	10	75	8765	26
25	9700	10	76	8739	26
26	9689	11	77	8712	27
27	9679	10	78	8685	27
28	9668	11	79	8658	27
29	9657	11	80	8631	27
30	9646	11	81	8603	28
31	9634	12	82	8575	28
32	9622	12	83	8547	28
33	9609	13	84	8518	29
34	9596	13	85	8488	30
35	9583	13	86	8458	30
36	9570	13	87	8428	30
37	9556	14	88	8397	31
38	9541	15	89	8365	32
39	9526	15	90	8332	33
40	9510	16	91	8299	33
41	9494	16	92	8265	34
42	9478	16	93	8230	35
43	9461	17	94	8194	36
44	9444	17	95	8157	37
45	9427	17	96	8118	39
46	9409	18	97	8077	41
47	9391	18	98	8034	43
48	9373	18	99	7988	46
49	9354	19	100	7939	49
50	9335	19			

The third column of this table exhibits the differences of the spec. gravs., in order to facilitate the calculation of fractions of percent-

age for spec. gravs. intermediate between those given in the table; the difference in the spec. gravs. as given in the third column becoming

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the denominator of the fraction; and the difference between the next greatest spec. grav. in the table, and that of the liquid in question, forming the numerator. Thus, if the spec. grav. of a spirit were found to be at 60° $=.9260$, this would indicate a percentage of between 53 and 54, or be 53 and a fraction, the numerator of which will be the difference between the spec. grav. for 53 per cent., and that of the spirit, $(.9260) = 15$, and the denominator, the difference between the spec. gravs. for 53 and 54, which is found in the third column $= 21$. The fraction will therefore be $\frac{15}{21}$, and the percentage of absolute alcohol for that liquid $= 53\frac{15}{21}$ or 53.71.

The percentage of alcohol by *weight* is obtained from the above table by first finding the *percentage by volume*, and then multiplying this number by .7939 (the spec. grav. of absolute alcohol), and dividing the product by the spec. grav. of the liquid in question. Thus, in the above example, the percentage by vol. $= 53.71$,

multiplied by 0.7939 is $= 42.64$; which divided by 0.9260 (the spec. grav. of the spirit), is $= 46.04$, or the spirit contains 46.04 per cent. by weight of absolute alcohol.

The preceding table requires that the spec. grav. of the liquid under trial be ascertained at the normal temperature of 60° . If, therefore, its temperature differ from it, the portion used for ascertaining the spec. grav. must first be artificially brought to the normal temperature, which is often inconvenient.

As it is therefore desirable to be able to calculate the percentage of alcohol in a spirit from the spec. grav. taken at any temperature, it is necessary to know the expansion or change in spec. grav. of the different alcoholic mixtures for different temperatures. This has also been ascertained and the results given by Tralles in the following table, showing the variation in the (real) spec. grav. of alcoholic liquids at different temperatures.

TABLE II.

Per cent. by vol. of absolute Alcohol.	Spec. grav. of the liquid at 60° .	Increase of spec. grav. at the indicated temperature <i>below</i> 60° .					
		$+ 55^{\circ}$	50°	45°	40°	35°	30°
0	0.9991	4	7	9	9	9	7
5	9919	4	7	9	10	10	9
10	9857	5	9	12	14	15	15
15	9802	6	12	17	21	23	25
20	9751	8	16	23	29	35	39
25	9700	10	21	31	39	48	56
30	9646	13	26	39	51	62	73
35	9583	16	31	46	61	75	89
40	9510	18	35	52	70	87	103
45	9427	19	39	57	76	94	112
50	9355	20	40	60	80	99	118
55	9234	21	42	63	84	104	124
60	9126	22	43	65	6	107	127
65	9013	22	45	67	88	109	130
70	8892	22	45	68	90	112	133
75	8765	23	46	68	91	113	135
80	8631	23	47	70	92	115	137
85	8488	23	47	70	93	116	139
90	8332	24	48	71	94	117	140

Per cent. by vol. of absolute Alcohol.	Spec. gravity of the liquid at 60° .	Decrease of spec. grav. at the indicated temperature <i>above</i> 60° .							
		65°	70°	75°	80°	85°	90°	95°	100°
0	0.9991	5	11	17	24	32	40	50	60
5	9919	5	11	18	25	33	42	51	62
10	9857	6	13	20	29	37	47	57	68
15	9802	7	15	25	34	44	55	67	79
20	9751	9	19	30	41	53	66	79	93
25	9700	11	24	36	50	63	78	93	109
30	9646	14	28	43	59	75	91	108	125
35	9583	17	33	50	68	86	104	122	141
40	9510	18	37	56	75	94	114	134	154
45	9427	20	40	60	80	101	122	143	164
50	9335	21	42	63	84	106	128	150	173
55	9234	22	43	65	87	109	132	155	178
60	9126	22	44	67	90	113	136	159	183
65	9013	22	45	68	92	115	138	162	187
70	8892	23	46	69	93	117	141	165	190
75	8765	23	46	70	94	119	143	167	192
80	8631	23	47	71	96	120	144	169	194
85	8488	24	48	72	96	121	145	170	195
90	8332	24	48	72	97	121	146	171	196

But as the spec. grav. of liquids at different temperatures is dependent on their expansion or contraction, which is always ascertained by vessels or instruments of glass or metal, which themselves expand or contract, the spec. grav. thus obtained are not the absolute or *real* spec. gravs., but merely *apparent*, that is, such as result from the difference in the expansion of

the liquids and the vessels or instruments by which they are ascertained. Tralles has calculated a third table, which exhibits these apparent spec. gravs., the use of which therefore is: to calculate the percentage of abs. alcohol by volume, in a liquid, from its spec. grav. ascertained at any temperature between 30° and 85° by a glass vessel or instrument.

TABLE III.

Per cent. of Alcohol by volume.	Spec. grav. of the liquid ascertained by glass instruments at the indicated temperatures.											
	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°
0	.9994	.9997	.9997	.9998	.9997	.9994	.9991	.9987	.9981	.9976	.9970	.9962
5	.9924	.9926	.9926	.9926	.9925	.9922	.9919	.9915	.9909	.9903	.9897	.9889
10	.9868	.9869	.9868	.9867	.9865	.9861	.9857	.9852	.9845	.9839	.9831	.9823
15	.9823	.9822	.9820	.9817	.9813	.9807	.9802	.9796	.9788	.9779	.9771	.9761
20	.9786	.9782	.9777	.9772	.9766	.9759	.9751	.9743	.9733	.9723	.9713	.9701
25	.9752	.9745	.9737	.9729	.9720	.9709	.9700	.9690	.9678	.9666	.9653	.9640
30	.9715	.9705	.9694	.9683	.9671	.9658	.9646	.9633	.9619	.9605	.9590	.9574
35	.9668	.9655	.9641	.9627	.9612	.9598	.9583	.9567	.9551	.9535	.9518	.9500
40	.9609	.9594	.9577	.9560	.9544	.9527	.9510	.9493	.9474	.9456	.9438	.9419
45	.9535	.9518	.9500	.9482	.9464	.9445	.9427	.9408	.9388	.9369	.9350	.9329
50	.9449	.9431	.9413	.9393	.9374	.9354	.9335	.9315	.9294	.9274	.9253	.9232
55	.9354	.9335	.9316	.9295	.9275	.9254	.9234	.9213	.9192	.9171	.9150	.9128
60	.9249	.9230	.9210	.9189	.9168	.9147	.9126	.9105	.9083	.9061	.9039	.9016
65	.9140	.9120	.9099	.9078	.9056	.9034	.9013	.8992	.8969	.8947	.8924	.8901
70	.9021	.9001	.8980	.8958	.8936	.8913	.8892	.8870	.8847	.8825	.8801	.8778
75	.8896	.8875	.8854	.8832	.8810	.8787	.8765	.8743	.8720	.8697	.8673	.8649
80	.8764	.8743	.8721	.8699	.8676	.8653	.8631	.8609	.8585	.8562	.8538	.8514
85	.8623	.8601	.8579	.8556	.8533	.8510	.8488	.8465	.8441	.8418	.8394	.8370
90	.8469	.8446	.8423	.8401	.8379	.8355	.8332	.8309	.8285	.8262	.8238	.8214

Reduction in the spec. grav. when ascertained by an instrument of brass before using the above table.

To be subtracted.	To be added.
— 5 | — 4 | — 3 | — 2 | — 2 | — 1	0 | + 1 | + 2 | + 2 | + 3 | + 4

For temperatures and spec. gravs. intermediate between those found in the table, the percentage must be calculated by interpolation, which is rather an inconvenience. An example will best illustrate its use. Suppose the spec. grav. of a spirit has been found 0.9360 at 78°; 78° is intermediate between 75° and 80°; we therefore refer to the two vertical columns under 75° and 80°, and find that the spec. grav. 0.9360 is intermediate between .9369 under 75° and .9350 under 80°, the difference = 19 is the difference in the spec. grav. for 5° (75° to 80°) or $\frac{19}{5}$, the difference for 1°; the difference between 75° and 78° is 3°, which therefore must make a difference in the spec. grav. of 3 times $\frac{19}{5} = 5\frac{1}{5}$ or $11\frac{2}{5}$, and therefore must be added to 0.9360 in order to reduce this spec. grav. to 75° ($0.9360 + 11\frac{2}{5} = 0.9371\frac{2}{5}$); or the spec. grav. of the spirit would be 0.9371 (omitting the fraction) at 75°. We then further observe, under the column for 75°, that this spec. grav. is intermediate between .9456 (the spec. grav. for 40 per cent. alcohol, see the horizontal column), and .9369 (the spec. grav. for 45 per cent. alcohol), its strength must therefore be between 40 and 45 per cent.; the difference in the spec. grav. for these 5 per cent. is 87 (.9456—9369=87). The difference between the spec. grav. for 40 per cent. and the spec.

grav. in question is 85 (.9456—9371=85). Therefore, as 87:5 per cent.=85:x, or 4.88 per cent. which must be added to 40 per cent., or the percentage of the liquid is 44.88.

In all the above calculations the percentage in volume of abs. alcohol. refers to the volume of the liquid when measured at 60°, whether its spec. grav. be taken at 60° (Table I.) or at any other temp. (Table III.). This percentage is therefore called its *strength*. But if, as in the sale or purchase of liquors, it be desired to know the absolute quantity of pure alcohol contained in the whole liquid, this must be measured at 60°, or its temp. observed at the time it is measured, and its volume at 60° then calculated from this temperature by the aid of Table II., the volumes being in an inverse ratio to the spec. grav. at the different temperatures.

To avoid this calculation, Tralles has calculated another table (Table IV.) which gives the quantity of absolute alcohol in reference to the volume of the liquid at the temperature at which it is measured, or its *richness*, on which, therefore, the value of the whole liquid, as measured, depends. But it is then necessary that the spec. grav. of it be taken exactly at the same temperature at which it is measured. The spec. grav. in this case is also to be ascertained by a glass instrument.

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TABLE IV.

To ascertain at any Temperature, from the Spec. Grav., the Quantity of Abs. Alcohol in a Liquid, expressed in per cent. of its Volume at that Temperature.

Per cent. of abs. alcohol, by vol. in the liquid, as measured.	Spec. grav. of the liquid ascertained by glass instruments at the indicated temperatures.											
	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°
0	0.9994	.9997	.9997	.9998	.9997	.9994	.9991	.9987	.9981	.9976	.9970	.9962
5	9924	9926	9926	9926	9925	9922	9919	9915	9909	9903	9897	9889
10	9868	9869	9868	9867	9865	9861	9857	9852	9845	9839	9831	9823
15	9823	9822	9820	9817	9813	9807	9802	9796	9788	9779	9771	9761
20	9786	9782	9777	9772	9766	9759	9751	9743	9733	9722	9711	9700
25	9753	9746	9738	9729	9720	9709	9700	9690	9678	9665	9652	9638
30	9717	9707	9695	9684	9672	9659	9646	9632	9618	9603	9588	9572
35	9671	9658	9644	9629	9614	9599	9583	9566	9549	9532	9514	9495
40	9615	9598	9581	9563	9546	9528	9510	9491	9472	9452	9433	9412
45	9544	9525	9506	9486	9467	9447	9427	9406	9385	9364	9342	9320
50	9460	9440	9420	9399	9378	9356	9335	9313	9290	9267	9244	9221
55	9368	9347	9325	9302	9279	9256	9234	9211	9187	9163	9139	9114
60	9267	9245	9222	9198	9174	9150	9126	9102	9076	9051	9026	9000
65	9162	9138	9113	9088	9063	9038	9013	8988	8962	8936	8909	8882
70	9046	9021	8996	8970	8944	8917	8892	8866	8839	8812	8784	8756
75	8925	8899	8873	8847	8820	8792	8765	8738	8710	8681	8652	8622
80	8798	8771	8744	8716	8688	8659	8631	8602	8573	8544	8514	8483
85	8663	8635	8606	8577	8547	8517	8488	8458	8427	8396	8365	8333
90	8517	8486	8455	8425	8395	8363	8332	8300	8268	8236	8204	8171

Reduction in the spec. grav. when ascertained by a brass instrument before using the above table.

To be added.						To be subtracted.					
+ 5	+ 4	+ 3	+ 2	+ 2	+ 1	0	— 1	— 2	— 2	— 3	— 4

The previous tables contain all that is requisite to the estimation of the quantity of alcohol in an alcoholic liquid by the specific gravity. This latter may be ascertained either by weighings in a spec. gravity bottle (see SPECIFIC GRAVITY of liquids), or by HYDROMETERS, which are more convenient for practical purposes. Beaumé's hydrometer is often employed for this purpose, it being only necessary to have a table to ascertain the spec. gravs. corresponding to its degrees. But it has been found more convenient to give to the hydro-

meters such a construction as to indicate directly the percentage of alcohol.

Hydrometers thus constructed receive the name of *alcoholometers*. They are generally made of glass, more rarely of brass, and are sometimes made to indicate the percentage by volume and by weight at the same time.

Tralles has given the following table for the construction of his alcoholometer, to indicate directly the per cent. of alcohol by vol. in a liquid at 60°.

TABLE V.

Per cent. alcohol by volume.	Length of immersed part of stem.	Distance between degrees of scale indicating pr. ct.	Per cent. alcohol by volume.	Length of immersed part of stem.	Distance between degrees of scale indicating pr. ct.	Per cent. alcohol by volume.	Length of immersed part of stem.	Distance between degrees of scale indicating pr. ct.	Per cent. alcohol by volume.	Length of immersed part of stem.	Distance between degrees of scale indicating pr. ct.
0	9		17	224	11	34	420	13	51	735	23
1	24	15	18	235	11	35	434	14	52	758	23
2	39	15	19	245	10	36	449	15	53	782	24
3	54	15	20	256	10	37	465	16	54	806	24
4	68	14	21	266	10	38	481	16	55	830	24
5	82	14	22	277	11	39	498	17	56	854	24
6	95	13	23	288	11	40	515	17	57	879	25
7	108	13	24	299	11	41	533	18	58	905	26
8	121	13	25	310	11	42	551	18	59	931	26
9	133	12	26	321	11	43	569	18	60	957	26
10	145	12	27	332	11	44	588	19	61	984	27
11	157	12	28	344	12	45	608	20	62	1011	27
12	169	12	29	355	11	46	628	20	63	1039	28
13	180	11	30	367	12	47	648	20	64	1067	28
14	191	11	31	380	13	48	669	21	65	1096	29
15	202	11	32	393	13	49	690	21	66	1125	29
16	213	11	33	407	14	50	712	22	67	1154	29

TABLE V.—Continued.

Per cent. alcohol by volume.	Length of immersed part of stem.	Distance between degrees of scale indicating per ct.	Per cent. alcohol by volume.	Length of immersed part of stem.	Distance between degrees of scale indicating per ct.	Per cent. alcohol by volume.	Length of immersed part of stem.	Distance between degrees of scale indicating per ct.	Per cent. alcohol by volume.	Length of immersed part of stem.	Distance between degrees of scale indicating per ct.
68	1184	30	77	1478	35	85	1781	41	93	2150	51
69	1215	31	78	1514	36	86	1823	42	94	2203	53
70	1246	31	79	1550	36	87	1866	43	95	2259	56
71	1278	32	80	1587	37	88	1910	44	96	2318	59
72	1310	32	81	1624	37	89	1955	45	97	2380	62
73	1342	32	82	1662	38	90	2002	47	98	2447	67
74	1375	33	83	1701	39	91	2050	48	99	2519	72
75	1409	34	84	1740	39	92	2099	49	100	2597	78
76	1443	34									

In order to use this table for graduating the alcoholometer, 2 liquids are required of 60° temp., the percentage of which has been ascertained with accuracy. Distilled water of 60° may be used as one of them. If, for instance, one be water, and the other spirit of 49 per cent., the 2 points are marked to which the alcoholometer sinks in them. The table then shows that by dividing the space between these points into 681 (690—9=681) smaller parts, the addition of 22 such parts will indicate the point for 50 per cent., 23 more, that for 51 per cent., &c. (3d column), and if 9 of these parts be added below zero, or the point to which it sinks in water, that point is obtained, the distance of which from the points of the different percentages is indicated by the numbers in 2d column of the table. Only a part of the scale may also be very easily graduated; as from liquids of 32 and 80 per cent., the numbers for the lower degrees are then merely subtracted, supposing, them to be situated in the bulb of the alcoholometer.

It is necessary that the stem of the alcoholometer should be perfectly cylindrical, but even if the inequalities do not exceed $\frac{1}{20}$ of the diameter, such a tube may be employed. Tubes of greater inequalities, or of a conical shape, must be rejected.

It is evident that these degrees of percentage of the alcoholometer are only correct when the spirituous liquid under trial has the normal temperature of 60°. If the temperature be different the percentage can only be ascertained by taking the specific gravity corresponding to the percentage on the alcoholometer, and then calculating the true percentage in the usual way by Table III. or IV.

To avoid this, Tralles has constructed two tables by which the *true* percentage may be obtained from the *observed*, indicated by the alcoholometer in a liquid the temp. of which is different from 60°. Of these, Table VI. corresponds to Table III., and gives the *strength*. (See Table III.)

TABLE VI.

To find the True Percentage of Abs. Alcoh. by Volume, in a Liquid at 60°, from the Observed Percentage indicated by a Glass Alcoholometer at any other Temperature.

32°	35°	40°	45°	50°	55°	60°	60°	65°	70°	75°	80°	85°
— 0.2	— 0.4	— 0.4	— 0.5	— 0.4	— 0.2	0	0	+ 0.2	+ 0.6	+ 1.0	+ 1.4	+ 1.9
+ 4.6	+ 4.5	+ 4.5	+ 4.5	+ 4.6	+ 4.8	5	5	5.3	5.8	6.2	6.7	7.3
9.1	9.0	9.1	9.2	9.3	9.7	10	10	10.4	11.0	11.6	12.3	13.0
13.0	13.1	13.3	13.5	13.9	14.5	15	15	15.6	16.3	17.1	18.0	19.0
16.5	16.9	17.4	17.8	18.5	19.2	20	20	20.8	21.8	22.8	23.8	24.9
19.9	20.6	21.4	22.2	23.0	24.1	25	25	25.9	27.0	28.2	29.4	30.5
23.5	24.5	25.7	26.6	27.7	28.8	30	30	31.1	32.2	33.4	34.5	35.7
28.0	29.2	30.4	31.6	32.7	33.8	35	35	36.2	37.3	38.4	39.5	40.6
33.0	34.2	35.4	36.7	37.8	39.0	40	40	41.1	42.2	43.3	44.3	45.4
38.4	39.6	40.7	41.8	42.9	43.9	45	45	46.1	47.1	48.2	49.2	50.3
43.7	44.7	45.8	46.9	47.9	49.0	50	50	51.0	52.0	53.0	54.0	55.1
49.0	50.0	51.0	52.0	53.0	54.0	55	55	54.9	56.9	57.9	58.9	59.9
54.2	55.2	56.2	57.1	58.1	59.0	60	60	60.9	61.9	62.9	63.8	64.9
59.4	60.3	61.2	62.2	63.1	64.0	65	65	65.9	66.8	67.7	68.6	69.6
64.6	65.5	66.4	67.3	68.2	69.1	70	70	70.8	71.7	72.6	73.5	74.5
69.8	70.7	71.5	72.4	73.3	74.2	75	75	75.8	76.7	77.6	78.4	79.3
75.0	75.8	76.6	77.5	78.4	79.2	80	80	80.8	81.7	82.4	83.2	84.1
80.3	81.1	81.8	82.6	83.5	84.3	85	85	85.7	86.5	87.3	88.0	88.8
85.6	86.4	87.1	87.9	88.6	89.3	90	90	90.7	91.4	92.0	92.7	93.4

The numbers in the vertical columns under the temperatures, are, of course, the observed degrees of the alcoholometer, indicating the percentage of abs. alcoh. by vol. Thus, if the alcoholometer indicated in a liquid 78.4 per cent. at 80°, it would be found by aid of the

ALCOHOLOMETER.

ALCOHOLOMETER.

table, that its true percentage was 75 when at the temp. of 60°.

The two following tables correspond to Table IV., excepting that Table VII. is for glass, and Table VIII. for brass alcoholometers. They give the richness or the per cent. of alcohol by vol.

in reference to the volume of the liquid at the temperature when tested. Like Table IV., it therefore requires that the liquid should be tested exactly at the same temperature at which it is measured.

TABLE VII.

To find the True Percentage of Abs. Alcohol, by Volume, in a Liquid of any Temperature, from the Observed Percentage indicated by the Glass Alcoholometer at the same Temperature.

True per ct. of alcohol, by volume.	Observed per cent. indicated by the glass alcoholometer.											
	30°	35°	40°	45°	50°	55°	65°	70°	75°	80°	85°	
0	— 0.2	— 0.4	— 0.4	— 0.5	— 0.4	— 0.2	+ 0.2	+ 0.6	+ 1.0	+ 1.4	+ 1.9	
5	+ 4.6	+ 4.5	+ 4.5	+ 4.5	+ 4.6	+ 4.8	5.3	5.8	6.2	6.7	7.3	
10	9.1	9.0	9.1	9.2	9.3	9.7	10.4	11.0	11.6	12.3	13.0	
15	13.0	13.1	13.3	13.6	14.1	14.5	15.6	16.3	17.1	18.0	19.0	
20	16.5	16.9	17.4	17.9	18.5	19.2	20.8	21.8	22.9	23.9	25.0	
25	19.8	20.5	21.3	22.2	23.0	24.1	25.9	27.1	28.3	29.5	30.7	
30	23.3	24.3	25.5	26.5	27.6	28.8	31.2	32.3	33.5	34.6	35.9	
35	27.7	28.9	30.2	31.4	32.6	33.8	36.3	37.5	38.6	39.7	40.9	
40	32.5	33.8	35.1	36.5	37.7	38.9	41.2	42.4	43.5	44.6	45.8	
45	37.8	39.1	40.3	41.5	42.7	43.8	46.2	47.3	48.5	49.6	50.8	
50	43.1	44.2	45.4	46.6	47.7	48.9	51.1	52.2	53.4	54.5	55.6	
55	48.3	49.4	50.5	51.6	52.8	53.9	56.1	57.2	58.3	59.4	60.5	
60	53.4	54.5	55.6	56.7	57.8	58.9	61.1	62.2	63.3	64.4	65.5	
65	58.4	59.5	60.6	61.7	62.8	63.9	66.0	67.1	68.2	69.3	70.4	
70	63.5	64.6	65.7	66.8	67.9	69.0	71.0	72.1	73.2	74.3	75.4	
75	68.6	69.7	70.7	71.8	72.9	74.0	76.0	77.1	78.2	79.2	80.3	
80	73.7	74.8	75.8	76.9	78.0	79.0	81.0	82.1	83.1	84.1	85.2	
85	78.8	79.8	80.9	81.9	83.0	84.0	86.0	87.0	88.0	89.0	90.0	
90	84.0	85.1	86.1	87.1	88.1	89.1	91.0	91.9	92.8	93.7	94.6	

Thus, if the alcoholometer indicated 59.4 per cent. in a liquid at 80°, the table would give its true percentage (richness) to 55 per cent., that

is, 100 vol. of the liquid at 80°, contains 55 vol. of anhyd. alcohol.

TABLE VIII.

To find the True Percentage of Abs. Alcohol, by Volume in a Liquid of any Temperature, from the Observed Percentage indicated by a Brass Alcoholometer at the same Temperature.

True per ct. of alcohol, by volume.	Observed percentage indicated by brass alcoholometer.											
	30°	35°	40°	45°	50°	55°	65°	70°	75°	80°	85°	
0	— 0.1	— 0.1	— 0.2	— 0.3	— 0.3	— 0.2	+ 0.2	+ 0.5	+ 0.9	+ 1.2	+ 1.7	
5	+ 5.0	+ 4.8	+ 4.7	+ 4.8	+ 4.7	+ 4.8	5.2	5.6	6.1	6.5	7.0	
10	9.5	9.4	9.4	9.4	9.5	9.7	10.3	10.8	11.4	12.0	12.6	
15	13.5	13.5	13.6	13.7	14.0	14.6	15.5	16.2	17.0	17.7	18.6	
20	17.0	17.3	17.7	18.1	18.7	19.3	20.7	21.6	22.7	23.7	24.6	
25	20.3	20.9	21.6	22.4	23.3	24.2	25.8	26.9	28.1	29.2	30.3	
30	23.8	24.7	25.8	26.8	27.8	28.9	31.1	32.2	33.3	34.4	35.5	
35	28.2	29.3	30.4	31.6	32.8	33.9	36.2	37.3	38.4	39.5	40.7	
40	32.9	34.1	35.4	36.7	37.9	39.0	41.1	42.2	43.4	44.5	45.6	
45	38.1	39.3	40.4	41.6	42.7	43.9	46.1	47.2	48.3	49.4	50.5	
50	43.4	44.5	45.6	46.7	47.8	48.9	51.1	52.2	53.3	54.4	55.5	
55	48.5	49.6	50.7	51.8	52.9	54.0	56.0	57.1	58.2	59.3	60.4	
60	53.6	54.6	55.7	56.8	57.8	58.9	61.0	62.1	63.2	64.3	65.3	
65	58.6	59.7	60.7	61.8	62.8	63.9	66.0	67.1	68.1	69.2	70.2	
70	63.7	64.8	65.8	66.9	67.9	69.0	71.0	72.1	73.1	74.2	75.2	
75	68.8	69.8	70.9	71.9	72.9	74.0	76.0	77.0	78.1	79.1	80.1	
80	73.9	74.9	75.9	76.9	78.0	79.0	81.0	82.0	83.0	84.0	85.0	
85	79.0	80.0	81.0	82.0	83.0	84.0	86.0	87.0	88.0	88.9	89.9	
90	84.2	85.2	86.2	87.2	88.1	89.1	90.9	91.9	92.8	93.7	94.5	

The eight tables of Tralles contain all that is necessary for estimating the quantity of alcohol in a liquid; but since then a very full essay has appeared on the same subject, by Gay-Lussac, (*Instruction pour l'usage de L'Alco-*

omètre centésimal et des Tables qui l'accompagnent. Paris, 1824), and as his tables are much fuller, and scarcely require any interpolation, we give them below in full.

Gay-Lussac's alcoholometer is constructed

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like a common glass hydrometer; and the degrees of its scale indicating, like those of Tralles, the per cent. of absolute alcohol by vol.; but the normal temperature for his is 59°, instead of 60°, and the water at the same temperature (59°) is taken as unity, instead of at its greatest density, or at 39·83°. His fundamental numbers determining the relation between the percentage of alcohol and the spec. gravs. differ also somewhat from those used by Tralles; but the resulting differences are so small that in practice they may be neglected. The following table exhibits these fundamental numbers of the percentage by vol., and the spec. gravs. of the different alcoholic mixtures at 59°. (See Table at top of next column.)

ALCOHOLOMETRY.

Per cent. of alcohol by volume.	Spec. grav. of the liquid at 59°.	Per cent. of alcohol by volume.	Spec. grav. of the liquid at 59°.
100	0·7947	60	0·9141
95	0·8168	55	0·9248
90	0·8346	50	0·9348
85	0·8502	45	0·9440
80	0·8645	40	0·9523
75	0·8799	35	0·9595
70	0·8907	10	0·9656
65	0·9027	0	1·0000

A somewhat differing table, which we subjoin, has been constructed by Marozeau, from experiments with one of Gay-Lussac's alcoholometers:—

Per ct. of alcohol by vol.	Specific gravity.	Per ct. of alcohol by vol.	Specific gravity.	Per ct. of alcohol by vol.	Specific gravity.
0	1·000	34	0·962	68	0·896
1	0·999	35	0·960	69	0·893
2	0·997	36	0·959	70	0·891
3	0·996	37	0·957	71	0·888
4	0·994	38	0·956	72	0·886
5	0·993	39	0·954	73	0·884
6	0·992	40	0·953	74	0·881
7	0·990	41	0·951	75	0·879
8	0·989	42	0·949	76	0·876
9	0·988	43	0·948	77	0·874
10	0·987	44	0·946	78	0·871
11	0·986	45	0·945	79	0·868
12	0·984	46	0·943	80	0·865
13	0·983	47	0·941	81	0·863
14	0·982	48	0·940	82	0·860
15	0·981	49	0·938	83	0·857
16	0·980	50	0·936	84	0·854
17	0·979	51	0·934	85	0·851
18	0·978	52	0·932	86	0·848
19	0·977	53	0·930	87	0·845
20	0·976	54	0·928	88	0·842
21	0·975	55	0·926	89	0·838
22	0·974	56	0·924	90	0·835
23	0·973	57	0·922	91	0·832
24	0·972	58	0·920	92	0·829
25	0·971	59	0·918	93	0·826
26	0·970	60	0·915	94	0·822
27	0·969	61	0·913	95	0·818
28	0·968	62	0·911	96	0·814
29	0·967	63	0·909	97	0·810
30	0·966	64	0·906	98	0·805
31	0·965	65	0·904	99	0·800
32	0·964	66	0·902	100	0·795
33	0·963	67	0·899		

The first of Gay-Lussac's tables is headed, "Table of real strength of spirits;" and corresponds to Table VI. of Tralles, giving the real percent. by vol. of the liquid at 59° from the observed percent. of the alcoholometer at other temperatures.

The numbers in the upper horizontal column are the observed percents. of the alcoholom.; while the large numbers in the vertical columns below them give the real percent. of the liquid at 59° (the strength), when tested at the temp. found in the left-hand vert. column. The small numbers under the real percents. indicate the vol. which 1000 vols. of the liquid would occupy at 59°; and which number, therefore, multiplied by the real percent. under which it stands, gives the richness, or absolute quantity of al-

cohol at the tested temp. For example: If the alcoholom. indicate 59 per cent. in a spirit at 77°, the observed per cent. (59) is sought for in the upper horiz. column; the number in the vert. column below this, which is in the same horizontal column with the temp. 77, found in the left-hand vert. column of temps. is the strength or real percent. of the liquid at 59°, being in this case 55·5. The number 992, found in small type immediately below it, is the vol. which 1000 vols. of the liquid would occupy at 59°, which vol. multiplied by the strength or real per cent. at 59°, 55·5, will give the richness in 1000 vols. at the tested temp. Thus,

$55·5 \times 992 = 550·56$, or 55·05 per cent. or, 100 vols. of the liquid at 77° contain 55·05 vols. of anhydrous alcohol.

TABLE I.

Alcoholometrical Table by Gay-Lussac, to find the Percent. by Vol., in a Liquid at 59° (Strength), from the Observed Percent. at any other Temperature. (The Temperature by Centigrade is below that of Fahr.)

Temp. Fahr.	Observed Percentage of the Alcoholometer.										Temp. Fahr.	Observed Percentage of the Alcoholometer.									
	1	2	3	4	5	6	7	8	9	10		11	12	13	14	15	16	17	18	19	20
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.		p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
32.0° 0° C.	1.3 1000	2.4 1000	3.4 1000	4.4 1000	5.4 1000	6.5 1001	7.5 1001	8.6 1001	9.7 1001	10.9 1001	32.0° 0° C.	12.2 1001	13.4 1002	14.7 1002	16.1 1002	17.5 1002	18.9 1003	20.3 1003	21.6 1004	22.9 1004	24.2 1004
33.8 1 C.											33.8 1 C.	13.4 1002	14.7 1002	16 1002	17.3 1002	18.7 1003	20 1003	21.3 1003	22.6 1004	23.9 1004	
35.6 2 C.											35.6 2 C.	13.4 1002	14.7 1002	16 1002	17.2 1002	18.5 1003	19.8 1003	21.1 1003	22.3 1004	23.6 1004	
37.4 3 C.											37.4 3 C.	13.3 1001	14.6 1002	15.9 1002	17.1 1002	18.3 1003	19.6 1003	20.8 1003	22 1003	23.3 1004	
39.2 4 C.											39.2 4 C.	13.3 1001	14.5 1002	15.8 1002	16.9 1002	18.1 1002	19.4 1002	20.6 1003	21.8 1003	23 1003	
41.0 5 C.	1.4 1001	2.5 1001	3.5 1001	4.5 1001	5.5 1001	6.6 1001	7.7 1001	8.7 1001	9.8 1001	10.9 1001	41.0 5 C.	12.1 1001	13.2 1001	14.4 1001	15.7 1002	16.8 1002	18 1002	19.2 1002	20.4 1003	21.5 1003	22.7 1003
42.8 6 C.											42.8 6 C.		13.1 1001	14.3 1001	15.6 1002	16.7 1002	17.8 1002	19 1002	20.2 1003	21.3 1003	22.4 1003
44.6 7 C.											44.6 7 C.		13 1001	14.2 1001	15.4 1001	16.6 1002	17.7 1002	18.8 1002	20 1002	21 1002	22.1 1002
46.4 8 C.											46.4 8 C.		13 1001	14.1 1001	15.3 1001	16.4 1001	17.5 1001	18.6 1002	19.7 1002	20.7 1002	21.8 1002
48.2 9 C.											48.2 9 C.		12.9 1001	14 1001	15.1 1001	16.2 1001	17.3 1001	18.4 1001	19.5 1001	20.5 1002	21.6 1002
50.0 10 C.	1.4 1000	2.4 1000	3.4 1001	4.5 1001	5.5 1001	6.5 1001	7.5 1001	8.5 1001	9.5 1001	10.6 1001	50.0 10 C.	11.7 1001	12.7 1001	13.8 1001	14.9 1001	16 1001	17 1001	18.1 1001	19.2 1001	20.2 1001	21.3 1001
51.8 11 C.	1.3 1000	2.4 1000	3.4 1000	4.4 1001	5.4 1001	6.4 1001	7.4 1001	8.4 1001	9.4 1001	10.5 1001	51.8 11 C.	11.6 1001	12.6 1001	13.6 1001	14.7 1001	15.8 1001	16.8 1001	17.9 1001	19 1001	20 1001	21 1001
53.6 12 C.	1.2 1000	2.3 1000	3.3 1000	4.3 1000	5.3 1000	6.3 1000	7.3 1000	8.3 1000	9.3 1000	10.4 1000	53.6 12 C.	11.5 1000	12.5 1001	13.5 1001	14.6 1001	15.6 1001	16.6 1001	17.6 1001	18.7 1001	19.7 1001	20.7 1001
55.4 13 C.	1.2 1000	2.2 1000	3.2 1000	4.2 1000	5.2 1000	6.2 1000	7.2 1000	8.2 1000	9.2 1000	10.3 1000	55.4 13 C.	11.4 1000	12.4 1000	13.4 1000	14.4 1000	15.4 1000	16.4 1000	17.4 1000	18.5 1000	19.5 1000	20.5 1000
57.2 14 C.	1.1 1000	2.1 1000	3.1 1000	4.1 1000	5.1 1000	6.1 1000	7.1 1000	8.1 1000	9.1 1000	10.2 1000	57.2 14 C.	11.2 1000	12.2 1000	13.2 1000	14.2 1000	15.2 1000	16.2 1000	17.2 1000	18.2 1000	19.2 1000	20.2 1000
59.0 15 C.	1 1000	2 1000	3 1000	4 1000	5 1000	6 1000	7 1000	8 1000	9 1000	10 1000	59.0 15 C.	11 1000	12 1000	13 1000	14 1000	15 1000	16 1000	17 1000	18 1000	19 1000	20 1000
60.8 16 C.	0.9 1000	1.9 1000	2.9 1000	3.9 1000	4.9 1000	5.9 1000	6.9 1000	7.9 1000	8.9 1000	9.9 1000	60.8 16 C.	10.9 1000	11.9 1000	12.9 1000	13.9 1000	14.9 1000	15.9 1000	16.9 1000	17.8 1000	18.7 1000	19.7 1000
62.6 17 C.	0.8 1000	1.8 1000	2.8 1000	3.8 1000	4.8 1000	5.8 1000	6.8 1000	7.8 1000	8.8 1000	9.8 1000	62.6 17 C.	10.8 1000	11.7 1000	12.7 1000	13.7 1000	14.7 1000	15.6 1000	16.6 1000	17.5 1000	18.4 1000	19.4 1000
64.4 18 C.	0.7 1000	1.7 1000	2.7 1000	3.7 1000	4.7 1000	5.7 1000	6.7 1000	7.7 1000	8.7 1000	9.7 1000	64.4 18 C.	10.7 1000	11.6 1000	12.5 1000	13.5 1000	14.5 1000	15.4 1000	16.3 1000	17.3 1000	18.2 1000	19.1 1000
66.2 19 C.	0.6 999	1.6 999	2.6 999	3.6 999	4.5 999	5.5 999	6.5 999	7.5 999	8.5 999	9.5 999	66.2 19 C.	10.5 999	11.4 999	12.4 999	13.3 999	14.3 999	15.2 999	16.1 999	17 999	17.9 999	18.8 999
68.0 20 C.	0.5 999	1.5 999	2.4 999	3.4 999	4.4 999	5.4 999	6.4 999	7.3 999	8.3 999	9.3 999	68.0 20 C.	10.3 999	11.2 999	12.2 999	13.1 999	14 999	14.9 999	15.8 999	16.7 999	17.6 999	18.5 999
69.8 21 C.	0.4 999	1.4 999	2.3 999	3.3 999	4.3 999	5.2 999	6.2 999	7.1 999	8.1 999	9.1 999	69.8 21 C.	10.1 999	11 999	11.9 999	12.8 999	13.7 999	14.6 999	15.5 999	16.4 999	17.3 999	18.2 999
71.6 22 C.	0.3 999	1.3 999	2.2 999	3.2 999	4.1 999	5.1 999	6.1 999	7 999	7.9 999	8.9 999	71.6 22 C.	9.9 999	10.8 999	11.7 999	12.6 999	13.5 999	14.4 999	15.3 999	16.2 999	17 999	17.9 999
73.4 23 C.	0.1 999	1.1 999	2.1 999	3.1 999	4 999	4.9 999	5.9 999	6.8 999	7.8 999	8.7 999	73.4 23 C.	9.7 999	10.6 999	11.5 999	12.4 999	13.3 999	14.1 999	15 999	15.9 999	16.7 999	17.6 999
75.2 24 C.	1 998	1.9 998	2.9 998	3.8 998	4.8 998	5.8 998	6.7 998	7.6 998	8.5 998		75.2 24 C.	9.5 998	10.4 998	11.3 998	12.2 998	13.1 998	13.9 998	14.8 998	15.7 998	16.5 997	17.4 997
77.0 25 C.	0.8 998	1.7 998	2.7 998	3.6 998	4.6 998	5.5 998	6.5 998	7.4 998	8.3 998		77.0 25 C.	9.3 998	10.2 998	11.1 998	12 998	12.8 998	13.6 998	14.5 997	15.4 997	16.2 997	17.1 997
78.8 26 C.	0.7 998	1.6 998	2.6 998	3.5 998	4.4 998	5.4 998	6.3 998	7.2 998	8.1 998		78.8 26 C.	9 998	9.9 997	10.8 997	11.7 997	12.6 997	13.4 997	14.2 997	15.1 997	15.9 997	16.8 997
80.6 27 C.	0.5 998	1.5 998	2.4 998	3.3 998	4.3 998	5.2 998	6.1 998	7 998	7.9 998		80.6 27 C.	8.8 997	9.7 997	10.6 997	11.5 997	12.3 997	13.1 997	14 997	14.8 997	15.6 997	16.5 997
82.4 28 C.	0.3 997	1.3 997	2.2 997	3.1 997	4.1 997	5 997	5.9 997	6.8 997	7.7 997		82.4 28 C.	8.6 997	9.5 997	10.3 997	11.2 997	12 997	12.8 996	13.7 996	14.5 996	15.3 996	16.1 996
84.2 29 C.	0.1 997	1.1 997	2 997	2.9 997	3.9 997	4.8 997	5.7 997	6.6 997	7.5 997		84.2 29 C.	8.4 997	9.2 997	10.1 997	11 997	11.8 996	12.6 996	13.4 996	14.2 996	15 996	15.8 996
86.0 30 C.	0.0 997	0.9 997	1.9 997	2.8 997	3.7 997	4.6 997	5.5 997	6.4 997	7.3 997		86.0 30 C.	8.1 997	9 996	9.8 996	10.7 996	11.5 996	12.3 996	13.1 996	13.9 996	14.7 996	15.5 996

ALCOHOLOMETRY.

ALCOHOLOMETRY.

TABLE I.—Continued.

Temp. Fahr.	Observed Percentage of the Alcoliometer.										Temp. Fahr.	Observed Percentage of the Alcoliometer.									
	21 p. c.	22 p. c.	23 p. c.	24 p. c.	25 p. c.	26 p. c.	27 p. c.	28 p. c.	29 p. c.	30 p. c.		31 p. c.	32 p. c.	33 p. c.	34 p. c.	35 p. c.	36 p. c.	37 p. c.	38 p. c.	39 p. c.	40 p. c.
32.0° 0° C.	25.6 1005	27 1005	28.4 1006	29.7 1006	30.9 1007	32.1 1007	33.2 1007	34.3 1008	35.3 1008	36.3 1008	32.0° 0° C.	37.3 1009	38.3 1009	39.2 10.9	40.2 10.9	41.1 1009	42.1 1010	43.1 1010	44 1010	45 1010	45.9 011
33.8 1 C.	25.3 1005	26.7 1005	28 1005	29.2 1006	30.4 1006	31.6 1006	32.7 1007	33.8 1007	34.8 1007	35.8 1008	33.8 1 C.	36.8 1008	37.8 1008	38.8 1008	39.8 1008	40.8 1009	41.8 1009	42.7 1009	43.7 1009	44.6 1010	45.5 1010
35.6 2 C.	24.9 1004	26.3 1005	27.5 1005	28.8 1006	30 1006	31.2 1006	32.3 1006	33.3 1006	34.4 1006	35.4 1007	35.6 2 C.	36.4 1007	37.4 1007	38.4 1008	39.4 1008	40.4 1008	41.4 1008	42.3 1008	43.3 1009	44.2 1009	45.1 1009
37.4 3 C.	24.6 1004	25.9 1005	27.1 1005	28.4 1005	29.6 1005	30.8 1005	31.9 1006	32.9 1006	33.9 1007	34.9 1007	37.4 3 C.	36 1007	37 1007	38 1007	39 1007	40 1007	41 1008	42 1008	42.9 1008	43.9 1008	44.8 1008
39.2 4 C.	24.3 1004	25.6 1005	26.8 1005	28 1005	29.2 1005	30.4 1005	31.4 1005	32.5 1005	33.5 1006	34.5 1006	39.2 4 C.	35.5 1006	36.5 1006	37.5 1006	38.5 1007	39.5 1007	40.5 1007	41.5 1007	42.5 1007	43.5 1007	44.4 1007
41.0 5 C.	24 1003	25.2 1003	26.4 1004	27.6 1004	28.8 1004	30 1004	31 1005	32.1 1005	33.1 1005	34.1 1005	41.0 5 C.	35.1 1005	36.1 1006	37.1 1006	38.1 1006	39.1 1006	40.1 1006	41.1 1006	42.1 1007	43.1 1007	44 1007
42.8 6 C.	23.6 1003	24.9 1004	26 1004	27.2 1004	28.4 1004	29.6 1004	30.6 1005	31.6 1005	32.6 1005	33.6 1005	42.8 6 C.	34.7 1005	35.7 1005	36.7 1005	37.7 1005	38.7 1005	39.7 1006	40.7 1006	41.6 1006	42.6 1006	43.6 1006
44.6 7 C.	23.3 1002	24.6 1003	25.7 1003	26.9 1003	28 1003	29.2 1003	30.2 1004	31.2 1004	32.2 1004	33.2 1004	44.6 7 C.	34.2 1004	35.2 1004	36.2 1005	37.2 1005	38.2 1005	39.2 1005	40.2 1005	41.2 1005	42.2 1005	43.2 1005
46.4 8 C.	23 1002	24.2 1003	25.3 1003	26.5 1003	27.6 1003	28.8 1003	29.8 1003	30.8 1003	31.8 1003	32.8 1003	46.4 8 C.	33.8 1004	34.8 1004	35.8 1004	36.8 1004	37.8 1004	38.8 1004	39.8 1004	40.8 1004	41.8 1004	42.8 1005
48.2 9 C.	22.7 1002	23.9 1002	25 1002	26.1 1002	27.2 1002	28.4 1003	29.4 1003	30.4 1003	31.4 1003	32.4 1003	48.2 9 C.	33.4 1003	34.4 1003	35.4 1003	36.4 1003	37.4 1004	38.4 1004	39.4 1004	40.4 1004	41.4 1004	42.4 1004
50.0 10 C.	22.4 1001	23.5 1002	24.6 1002	25.7 1002	26.8 1002	27.9 1002	29 1002	30 1002	31 1002	32 1002	50.0 10 C.	33 1002	34 1002	35 1003	36 1003	37 1003	38 1003	39 1003	40 1003	41 1003	42 1003
51.8 11 C.	22.1 1001	23.2 1001	24.3 1001	25.4 1001	26.5 1002	27.6 1002	28.6 1002	29.6 1002	30.6 1002	31.6 1002	51.8 11 C.	32.6 1002	33.6 1002	34.6 1002	35.6 1002	36.6 1002	37.6 1002	38.6 1002	39.6 1002	40.6 1002	41.6 1003
53.6 12 C.	21.8 1001	22.9 1001	24 1001	25.1 1001	26.1 1001	27.2 1001	28.2 1001	29.2 1001	30.2 1001	31.2 1001	53.6 12 C.	32.2 1001	33.2 1001	34.2 1001	35.2 1001	36.2 1002	37.2 1002	38.2 1002	39.2 1002	40.2 1002	41.2 1002
55.4 13 C.	21.5 1001	22.6 1001	23.6 1001	24.7 1001	25.7 1001	26.8 1001	27.8 1001	28.8 1001	29.8 1001	30.8 1001	55.4 13 C.	31.8 1001	32.8 1001	33.8 1001	34.8 1001	35.8 1001	36.8 1001	37.8 1001	38.8 1001	39.8 1001	40.8 1001
57.2 14 C.	21.2 1000	22.3 1000	23.3 1000	24.3 1000	25.3 1000	26.4 1000	27.4 1000	28.4 1000	29.4 1000	30.4 1000	57.2 14 C.	31.4 1000	32.4 1000	33.4 1000	34.4 1001	35.4 1001	36.4 1001	37.4 1001	38.4 1001	39.4 1001	40.4 1001
59.0 15 C.	21 1000	22 1000	23 1000	24 1000	25 1000	26 1000	27 1000	28 1000	29 1000	30 1000	59.0 15 C.	31 1000	32 1000	33 1000	34 1000	35 1000	36 1000	37 1000	38 1000	39 1000	40 1000
60.8 16 C.	20.7 1000	21.7 1000	22.7 1000	23.7 1000	24.7 1000	25.7 1000	26.6 1000	27.6 1000	28.6 1000	29.6 1000	60.8 16 C.	30.6 1000	31.6 1000	32.5 999	33.5 999	34.5 999	35.5 999	36.5 999	37.5 999	38.5 999	39.5 999
62.6 17 C.	20.4 999	21.4 999	22.4 999	23.4 999	24.4 999	25.4 999	26.3 999	27.3 999	28.2 999	29.2 999	62.6 17 C.	30.2 999	31.2 999	32.1 999	33.1 999	34.1 999	35.1 999	36.1 999	37.1 999	38.1 999	39.1 999
64.4 18 C.	20.1 999	21.1 999	22 999	23 999	24 999	25 999	25.9 999	26.9 999	27.8 999	28.8 999	64.4 18 C.	29.8 999	30.8 999	31.7 998	32.7 998	33.7 998	34.7 998	35.7 998	36.7 998	37.7 998	38.7 998
66.2 19 C.	19.8 999	20.8 999	21.7 999	22.7 998	23.6 998	24.6 998	25.5 998	26.5 998	27.4 998	28.4 998	66.2 19 C.	29.4 998	30.4 998	31.3 998	32.3 998	33.3 998	34.3 998	35.3 998	36.3 998	37.3 997	38.3 997
68.0 20 C.	19.5 999	20.5 998	21.4 998	22.4 998	23.3 998	24.3 998	25.2 998	26.1 998	27.1 998	28 998	68.0 20 C.	29 998	30 998	30.9 997	31.9 997	32.9 997	33.9 997	34.9 997	35.9 997	36.9 997	37.9 997
69.8 21 C.	19.1 998	20.1 998	21.1 998	22.1 998	23 998	23.9 998	24.8 998	25.7 998	26.7 997	27.6 997	69.8 21 C.	28.6 997	29.6 997	30.5 997	31.5 997	32.5 997	33.5 997	34.5 997	35.5 996	36.5 996	37.5 996
71.6 22 C.	18.8 998	19.8 998	20.7 997	21.7 997	22.6 997	23.6 997	24.4 997	25.3 997	26.3 997	27.2 997	71.6 22 C.	28.2 997	29.2 997	30.1 996	31.1 996	32.1 996	33.1 996	34.1 996	35.1 996	36.1 996	37.1 996
73.4 23 C.	18.5 998	19.5 997	20.4 997	21.4 997	22.3 997	23.2 997	24.1 997	25 997	25.9 997	26.8 997	73.4 23 C.	27.8 996	28.8 996	29.7 996	30.7 996	31.7 996	32.7 996	33.7 996	34.7 995	35.7 995	36.7 995
75.2 24 C.	18.3 997	19.2 997	20.1 997	21.1 997	21.9 997	22.8 997	23.7 996	24.6 996	25.5 996	26.4 996	75.2 24 C.	27.4 996	28.4 996	29.3 995	30.3 995	31.3 995	32.3 995	33.3 995	34.3 995	35.3 995	36.3 995
77.0 25 C.	18 997	18.9 997	19.8 997	20.7 997	21.6 996	22.5 996	23.3 996	24.3 996	25.2 996	26.1 996	77.0 25 C.	27 995	28 995	28.9 995	29.9 995	30.9 995	31.9 994	32.9 994	33.9 994	34.9 994	35.9 994
78.8 26 C.	17.7 997	18.6 996	19.5 996	20.4 996	21.3 996	22.2 995	23 995	23.9 995	24.8 995	25.7 995	78.8 26 C.	26.6 995	27.6 995	28.5 994	29.5 994	30.5 994	31.5 994	32.5 993	33.5 993	34.5 993	35.5 993
80.6 27 C.	17.4 996	18.3 996	19.2 996	20.1 996	20.9 996	21.8 996	22.7 996	23.6 996	24.4 995	25.3 995	80.6 27 C.	26.2 995	27.2 994	28.1 994	29.1 994	30.1 994	31.1 993	32.1 993	33.1 993	34.1 993	35.1 993
82.4 28 C.	17 996	18 996	18.9 995	19.7 995	20.6 995	21.5 995	22.3 995	23.2 995	24 994	24.9 994	82.4 28 C.	25.8 994	26.8 994	27.7 993	28.7 993	29.7 993	30.7 993	31.7 992	32.7 992	33.7 992	34.7 992
84.2 29 C.	16.7 996	17.6 996	18.5 995	19.4 995	20.3 995	21.1 995	21.9 994	22.8 994	23.7 994	24.5 994	84.2 29 C.	25.4 994	26.4 993	27.3 993	28.3 993	29.3 993	30.3 992	31.3 992	32.3 992	33.3 992	34.3 992
86.0 30 C.	16.4 995	17.3 995	18.2 995	19.1 995	19.9 994	20.8 994	21.6 994	22.5 994	23.3 994	24.2 994	86.0 30 C.	25.1 993	26 993	26.9 993	27.9 993	28.9 992	29.9 992	30.9 992	31.9 991	32.9 991	33.9 991

ALCOHOLOMETRY.

ALCOHOLOMETRY.

TABLE I.—Continued.

Temp. Fahr.	Observed Percentage of the Alcolometer.										Temp. Fahr.	Observed Percentage of the Alcolometer.									
	41 p. c.	42 p. c.	43 p. c.	44 p. c.	45 p. c.	46 p. c.	47 p. c.	48 p. c.	49 p. c.	50 p. c.		51 p. c.	52 p. c.	53 p. c.	54 p. c.	55 p. c.	56 p. c.	57 p. c.	58 p. c.	59 p. c.	60 p. c.
32.0° 0° C.	46.9 1011	47.9 1011	48.8 1011	49.8 1011	50.7 1011	51.7 1011	52.6 1012	53.5 1012	54.5 1012	55.4 1012	32.0° 0° C.	56.4 1012	57.3 1012	58.3 1012	59.2 1012	60.2 1012	61.2 1012	62.1 1012	63.1 1013	64.1 1013	65 1013
33.8 1 C.	46.5 1010	47.5 1010	48.4 1010	49.4 1010	50.3 1010	51.3 1011	52.2 1011	53.2 1011	54.2 1011	55.1 1011	33.8 1 C.	56 1011	57 1011	57.9 1011	58.9 1011	59.9 1011	60.9 1011	61.8 1011	62.8 1012	63.8 1012	64.7 1012
35.6 2 C.	46.1 1009	47.1 1009	48.1 1009	49 1009	49.9 1010	50.9 1010	51.8 1010	52.8 1010	53.8 1010	54.7 1010	35.6 2 C.	55.7 1010	56.6 1010	57.6 1010	58.5 1010	59.5 1010	60.5 1011	61.5 1011	62.4 1011	63.4 1011	64.4 1011
37.4 3 C.	45.8 1008	46.7 1009	47.7 1009	48.6 1009	49.6 1009	50.5 1009	51.5 1009	52.4 1009	53.4 1009	54.3 1009	37.4 3 C.	55.3 1009	56.3 1009	57.2 1009	58.2 1009	59.2 1009	60.2 1010	61.1 1010	62.1 1010	63.1 1010	64.1 1010
39.2 4 C.	45.4 1005	46.4 1005	47.4 1008	48.3 1008	49.2 1008	50.2 1008	51.1 1008	52.1 1008	53 10.8	54 10.9	39.2 4 C.	55 1009	56 1009	56.9 1009	57.9 1009	58.9 1009	59.8 1009	60.8 1009	61.7 1009	62.7 1009	63.7 1009
41.0 5 C.	45 1007	45.9 1007	46.9 1007	47.9 1007	48.8 1007	49.8 1007	50.7 1007	51.7 1007	52.7 1008	53.6 1008	41.0 5 C.	54.6 1008	55.6 1008	56.6 1008	57.5 1008	58.5 1008	59.5 1008	60.4 1008	61.4 1008	62.4 1008	63.4 1008
42.8 6 C.	44.6 1006	45.5 1006	46.5 1006	47.5 1007	48.4 1007	49.4 1007	50.4 1007	51.4 1007	52.4 1007	53.3 1007	42.8 6 C.	54.3 1007	55.2 1007	56.2 1007	57.1 1007	58.1 1007	59.1 1007	60.1 1007	61 1008	62 1008	63 1008
44.6 7 C.	44.2 1005	45.1 1006	46.1 1006	47.1 1006	48.1 1006	49.1 1006	50.1 1006	51 1006	52 1006	52.9 1006	44.6 7 C.	53.9 1006	54.9 1006	55.9 1006	56.8 1006	57.8 1006	58.8 1006	59.8 1006	60.7 1007	61.7 1007	62.7 1007
46.4 8 C.	43.8 1005	44.8 1005	45.8 1005	46.8 1005	47.7 1005	48.7 1005	49.7 1005	50.6 1005	51.6 1005	52.6 1005	46.4 8 C.	53.6 1005	54.6 1005	55.5 1006	56.5 1006	57.5 1006	58.5 1006	59.5 1006	60.4 1006	61.4 1006	62.4 1006
48.2 9 C.	43.4 1004	44.4 1004	45.4 1004	46.4 1004	47.3 1004	48.3 1004	49.3 1005	50.2 1005	51.2 1005	52.2 1005	48.2 9 C.	53.2 1005	54.2 1005	55.1 1005	56.1 1005	57.1 1005	58.1 1005	59.1 1005	60 1005	61 1005	62 1005
50.0 10 C.	43 1003	44 1004	45 1004	46 1004	46.9 1004	47.9 1004	48.9 1004	49.9 1004	50.9 1004	51.8 1004	50.0 10 C.	52.8 1004	53.8 1004	54.8 1004	55.8 1004	56.8 1004	57.8 1004	58.8 1004	59.7 1004	60.7 1004	61.7 1004
51.8 11 C.	42.6 1003	43.6 1003	44.6 1003	45.6 1003	46.6 1003	47.6 1003	48.6 1003	49.5 1003	50.5 1003	51.5 1003	51.8 11 C.	52.5 1003	53.5 1003	54.4 1003	55.4 1003	56.4 1003	57.4 1003	58.4 1003	59.4 1003	60.4 1003	61.4 1003
53.6 12 C.	42.2 1002	43.2 1002	44.2 1002	45.2 1002	46.2 1002	47.2 1002	48.2 1002	49.2 1002	50.2 1002	51.1 1002	53.6 12 C.	52.1 1002	53.1 1002	54.1 1002	55 1002	56 1002	57 1002	58 1002	59 1002	60 1002	61 1002
55.4 13 C.	41.8 1001	42.8 1001	43.8 1001	44.8 1002	45.8 1002	46.8 1002	47.8 1002	48.8 1002	49.8 1002	50.8 1002	55.4 13 C.	51.8 1002	52.7 1002	53.7 1002	54.7 1002	55.7 1002	56.7 1002	57.7 1002	58.7 1002	59.7 1002	60.7 1002
57.2 14 C.	41.4 1001	42.4 1001	43.4 1001	44.4 1001	45.4 1001	46.4 1001	47.4 1001	48.4 1001	49.4 1001	50.4 1001	57.2 14 C.	51.4 1001	52.3 1001	53.3 1001	54.3 1001	55.3 1001	56.3 1001	57.3 1001	58.3 1001	59.3 1001	60.3 1001
59.0 15 C.	41 1000	42 1000	43 1000	44 1000	45 1000	46 1000	47 1000	48 1000	49 1000	50 1000	59.0 15 C.	51 1000	52 1000	53 1000	54 1000	55 1000	56 1000	57 1000	58 1000	59 1000	60 1000
60.8 16 C.	40.6 999	41.6 999	42.6 999	43.6 999	44.6 999	45.6 999	46.6 999	47.6 999	48.6 999	49.6 999	60.8 16 C.	50.6 999	51.6 999	52.6 999	53.6 999	54.6 999	55.6 999	56.6 999	57.6 999	58.6 999	59.6 999
62.6 17 C.	40.2 999	41.2 999	42.2 999	43.2 998	44.2 998	45.2 998	46.2 998	47.2 998	48.3 998	49.3 998	62.6 17 C.	50.3 998	51.3 998	52.3 998	53.3 998	54.3 998	55.3 998	56.3 998	57.3 998	58.3 998	59.3 998
64.4 18 C.	39.8 998	40.8 998	41.8 998	42.8 998	43.8 998	44.9 998	45.9 998	46.9 998	47.9 998	48.9 998	64.4 18 C.	49.9 998	50.9 998	51.9 998	52.9 998	53.9 998	54.9 998	55.9 998	56.9 997	57.9 997	58.9 997
66.2 19 C.	39.4 997	40.4 997	41.4 997	42.5 997	43.5 997	44.5 997	45.5 997	46.5 997	47.5 997	48.5 997	66.2 19 C.	49.5 997	50.6 997	51.6 997	52.6 997	53.6 997	54.6 997	55.6 997	56.6 997	57.6 997	58.6 997
68.0 20 C.	39 997	40 997	41 997	42.1 997	43.1 996	44.1 996	45.1 996	46.1 996	47.2 996	48.2 996	68.0 20 C.	49.2 996	50.2 996	51.2 996	52.2 996	53.2 996	54.2 996	55.2 996	56.2 996	57.2 996	58.2 996
69.8 21 C.	38.6 996	39.6 996	40.6 996	41.7 996	42.7 996	43.7 996	44.8 996	45.8 996	46.8 995	47.8 995	69.8 21 C.	48.8 995	49.8 995	50.8 995	51.8 995	52.9 995	53.9 995	54.9 995	55.9 995	56.9 995	57.9 995
71.6 22 C.	38.2 996	39.2 995	40.2 995	41.3 995	42.3 995	43.3 995	44.3 995	45.3 995	46.4 995	47.4 995	71.6 22 C.	48.4 995	49.4 995	50.4 995	51.4 994	52.5 994	53.5 994	54.5 994	55.5 994	56.5 994	57.5 994
73.4 23 C.	37.8 995	38.8 995	39.8 994	40.9 994	41.9 994	42.9 994	43.9 994	44.9 994	46 994	47 994	73.4 23 C.	48 994	49.1 994	50.1 994	51.1 994	52.1 994	53.1 994	54.1 993	55.1 993	56.1 993	57.1 993
75.2 24 C.	37.4 994	38.4 994	39.4 994	40.5 994	41.5 994	42.5 994	43.6 994	44.6 994	45.6 993	46.6 993	75.2 24 C.	47.6 993	48.7 993	49.7 993	50.7 993	51.8 993	52.8 993	53.8 993	54.8 993	55.8 993	56.8 993
77.0 25 C.	37 994	38 994	39 993	40.1 993	41.1 993	42.2 993	43.2 993	44.2 993	45.2 993	46.3 993	77.0 25 C.	47.3 993	48.3 993	49.3 992	50.3 992	51.4 992	52.4 992	53.4 992	54.4 992	55.5 992	56.5 992
78.8 26 C.	36.5 993	37.6 993	38.6 993	39.7 992	40.7 992	41.8 992	42.8 992	43.8 992	44.9 992	45.9 992	78.8 26 C.	46.9 992	47.9 992	49 991	50 991	51 991	52 991	53 991	54 991	55.1 991	56.1 991
80.6 27 C.	36.1 992	37.2 992	38.2 992	39.3 992	40.3 992	41.4 992	42.4 992	43.4 991	44.5 991	45.5 991	80.6 27 C.	46.5 991	47.6 991	48.6 991	49.6 991	50.7 990	51.7 990	52.7 990	53.7 990	54.8 990	55.8 990
82.4 28 C.	35.7 992	36.8 992	37.8 992	38.9 991	39.9 991	41 991	42 991	43 991	44.1 991	45.1 990	82.4 28 C.	46.1 990	47.2 990	48.2 990	49.2 990	50.3 990	51.3 990	52.3 990	53.3 990	54.4 990	55.4 990
84.2 29 C.	35.3 991	36.3 991	37.4 991	38.5 991	39.5 990	40.6 990	41.6 990	42.6 990	43.7 990	44.7 990	84.2 29 C.	45.7 990	46.8 990	47.8 990	48.9 990	49.9 990	51 990	52 990	53 990	54 990	55 990
86.0 30 C.	34.9 991	35.9 991	37 990	38.1 990	39.1 990	40.2 990	41.2 990	42.3 990	43.3 990	44.3 990	86.0 30 C.	45.4 990	46.4 990	47.5 990	48.5 990	49.6 990	50.6 990	51.6 990	52.6 990	53.6 990	54.7 990

ALCOHOLOMETRY.

ALCOHOLOMETRY.

TABLE I.—Continued.

Temp. Fahr.	Observed Percentage of the Alcolometer.										Temp. Fahr.	Observed Percentage of the Alcolometer.									
	61 p. c.	62 p. c.	63 p. c.	64 p. c.	65 p. c.	66 p. c.	67 p. c.	68 p. c.	69 p. c.	70 p. c.		71 p. c.	72 p. c.	73 p. c.	74 p. c.	75 p. c.	76 p. c.	77 p. c.	78 p. c.	79 p. c.	80 p. c.
32-0° 0° C.	66 1013	67 1013	68 1013	68-9 1013	69-9 1013	70-8 1013	71-8 1013	72-7 1013	73-7 1013	74-7 1013	32-0° 0° C.	75-6 1014	76-6 1014	77-6 1014	78-6 1014	79-5 1014	80-5 1014	81-5 1014	82-4 1014	83-3 1014	84-3 1014
33-8 1 C.	65-7 1012	66-7 1012	67-7 1012	68-6 1012	69-6 1012	70-5 1012	71-5 1012	72-4 1012	73-4 1013	74-3 1013	33-8 1 C.	75-3 1013	76-3 1013	77-3 1013	78-3 1013	79-2 1013	80-2 1013	81-2 1013	82-1 1013	83-1 1013	84 1013
35-6 2 C.	65-3 1011	66-3 1011	67-3 1011	68-3 1011	69-3 1011	70-2 1011	71-2 1011	72-1 1012	73-1 1012	74 1012	35-6 2 C.	75 1012	76 1012	77 1012	78 1012	78-9 1012	79-9 1012	80-9 1012	81-9 1012	82-8 1012	83-7 1012
37-4 3 C.	65 1010	66 1010	67 1010	68 1010	68-9 1010	69-9 1011	70-8 1011	71-8 1011	72-8 1011	73-7 1011	37-4 3 C.	74-7 1011	75-7 1011	76-7 1011	77-7 1011	78-6 1011	79-6 1011	80-6 1011	81-6 1011	82-5 1011	83-5 1011
39-2 4 C.	64-7 1009	65-7 1009	66-6 1009	67-6 1010	68-6 1010	69-5 1010	70-5 1010	71-5 1010	72-5 1010	73-4 1010	39-2 4 C.	74-4 1010	75-3 1010	76-3 1010	77-3 1010	78-3 1010	79-3 1010	80-3 1010	81-3 1010	82-2 1010	83-2 1010
41-0 5 C.	64-3 1009	65-3 1009	66-3 1009	67-3 1009	68-3 1009	69-2 1009	70-2 1009	71-2 1009	72-2 1009	73-1 1009	41-0 5 C.	74-1 1009	75 1009	76 1009	77 1009	78 1009	79 1009	80 1009	81 1009	81-9 1010	82-9 1010
42-8 6 C.	64 1008	65 1008	66 1008	67 1008	68 1008	68-9 1008	69-9 1008	70-9 1008	71-9 1008	72-8 1008	42-8 6 C.	73-8 1008	74-7 1008	75-7 1008	76-7 1008	77-7 1008	78-7 1008	79-7 1008	80-7 1008	81-6 1008	82-6 1008
44-6 7 C.	63-7 1007	64-7 1007	65-7 1007	66-7 1007	67-6 1007	68-6 1007	69-6 1007	70-6 1007	71-5 1007	72-5 1007	44-6 7 C.	73-5 1007	74-4 1007	75-4 1007	76-4 1007	77-4 1007	78-4 1007	79-4 1007	80-4 1007	81-4 1007	82-3 1008
46-4 8 C.	63-4 1006	64-4 1006	65-4 1006	66-4 1006	67-3 1006	68-3 1006	69-3 1006	70-2 1006	71-2 1006	72-2 1006	46-4 8 C.	73-2 1006	74-1 1006	75-1 1006	76-1 1006	77-1 1006	78-1 1006	79-1 1006	80-1 1006	81-1 1006	82 1007
48-2 9 C.	63 1005	64 1005	65 1005	66 1005	67 1005	67-9 1005	68-9 1005	69-9 1005	70-9 1005	71-9 1005	48-2 9 C.	72-9 1005	73-8 1005	74-8 1005	75-8 1005	76-8 1005	77-8 1005	78-8 1005	79-8 1006	80-8 1006	81-7 1006
50-0 10 C.	62-7 1004	63-7 1004	64-7 1004	65-7 1004	66-7 1004	67-6 1004	68-6 1004	69-6 1004	70-6 1004	71-6 1004	50-0 10 C.	72-6 1004	73-5 1004	74-5 1005	75-5 1005	76-5 1005	77-5 1005	78-5 1005	79-5 1005	80-5 1005	81-5 1005
51-8 11 C.	62-4 1003	63-4 1003	64-4 1003	65-4 1003	66-4 1003	67-3 1003	68-3 1003	69-3 1004	70-3 1004	71-3 1004	51-8 11 C.	72-3 1004	73-2 1004	74-2 1004	75-2 1004	76-2 1004	77-2 1004	78-2 1004	79-2 1004	80-2 1004	81-2 1004
53-6 12 C.	62 1002	63 1002	64 1002	65 1002	66 1002	67 1002	68 1002	69 1003	70 1003	71 1003	53-6 12 C.	72 1002	72-9 1003	73-9 1003	74-9 1003	75-9 1003	76-9 1003	77-9 1003	78-9 1003	79-9 1003	80-9 1003
55-4 13 C.	61-7 1002	62-7 1002	63-7 1002	64-7 1002	65-7 1002	66-7 1002	67-7 1002	68-7 1002	69-6 1002	70-6 1002	55-4 13 C.	71-6 1002	72-6 1002	73-6 1002	74-6 1002	75-6 1002	76-6 1002	77-6 1002	78-6 1002	79-6 1002	80-6 1002
57-2 14 C.	61-3 1001	62-3 1001	63-3 1001	64-3 1001	65-3 1001	66-3 1001	67-3 1001	68-3 1001	69-3 1001	70-3 1001	57-2 14 C.	71-3 1001	72-3 1001	73-3 1001	74-3 1001	75-3 1001	76-3 1001	77-3 1001	78-3 1001	79-3 1001	80-3 1001
59-0 15 C.	61 1000	62 1000	63 1000	64 1000	65 1000	66 1000	67 1000	68 1000	69 1000	70 1000	59-0 15 C.	71 1000	72 1000	73 1000	74 1000	75 1000	76 1000	77 1000	78 1000	79 1000	80 1000
60-8 16 C.	60-6 999	61-7 999	62-7 999	63-7 999	64-7 999	65-7 999	66-7 999	67-7 999	68-7 999	69-7 999	60-8 16 C.	70-7 999	71-7 999	72-7 999	73-7 999	74-7 999	75-7 999	76-7 999	77-7 999	78-7 999	79-7 999
62-6 17 C.	60-3 998	61-3 998	62-3 998	63-3 998	64-3 998	65-3 998	66-3 998	67-3 998	68-3 998	69-3 998	62-6 17 C.	70-3 998	71-3 998	72-3 998	73-3 998	74-3 998	75-4 998	76-4 998	77-4 998	78-4 998	79-4 998
64-4 18 C.	59-9 997	61 997	62 997	63 997	64 997	65 997	66 997	67 997	68 997	69 997	64-4 18 C.	70 997	71 997	72 997	73 997	74 997	75-1 997	76-1 997	77-1 997	78-1 997	79-1 997
66-2 19 C.	59-6 997	60-6 997	61-6 997	62-7 997	63-7 997	64-7 997	65-7 997	66-7 997	67-7 997	68-7 996	66-2 19 C.	69-7 996	70-7 996	71-7 996	72-7 996	73-7 996	74-7 996	75-8 996	76-8 996	77-8 996	78-8 996
68-0 20 C.	59-2 996	60-3 996	61-3 996	62-3 996	63-3 996	64-3 996	65-4 996	66-4 996	67-4 996	68-4 996	68-0 20 C.	69-4 996	70-4 996	71-4 996	72-4 996	73-4 996	74-4 996	75-5 996	76-5 996	77-5 996	78-5 996
69-8 21 C.	58-9 995	59-9 995	61 995	62 995	63 995	64 995	65 995	66 995	67 995	68-1 995	69-8 21 C.	69-1 995	70-1 995	71-1 995	72-1 994	73-1 994	74-1 994	75-2 994	76-2 994	77-2 994	78-2 994
71-6 22 C.	58-5 994	59-5 994	60-6 994	61-6 994	62-7 994	63-7 994	64-7 994	65-7 994	66-7 994	67-8 994	71-6 22 C.	68-8 994	69-8 994	70-8 994	71-8 994	72-8 994	73-8 994	74-8 994	75-9 994	76-9 994	77-9 994
73-4 23 C.	58-1 993	59-2 993	60-2 993	61-3 993	62-3 993	63-3 993	64-3 993	65-4 993	66-4 993	67-4 993	73-4 23 C.	68-4 993	69-4 993	70-5 993	71-5 993	72-5 992	73-5 992	74-5 992	75-5 992	76-6 992	77-6 992
75-2 24 C.	57-8 992	58-9 992	59-9 992	61 992	62 992	63 992	64 992	65 992	66 992	67-1 992	75-2 24 C.	68-1 992	69-1 992	70-1 992	71-2 992	72-2 992	73-2 992	74-2 992	75-2 992	76-3 992	77-3 991
77-0 25 C.	57-5 992	58-5 992	59-5 992	60-6 991	61-6 991	62-6 991	63-7 991	64-7 991	65-7 991	66-7 991	77-0 25 C.	67-8 991	68-8 991	69-8 991	70-8 991	71-8 991	72-8 991	73-9 991	74-9 991	76 991	77 991
78-8 26 C.	57-1 991	58-1 991	59-2 991	60-2 991	61-3 990	62-3 990	63-3 990	64-3 990	65-3 990	66-4 990	78-8 26 C.	67-4 990	68-4 990	69-5 990	70-5 990	71-5 990	72-5 990	73-6 990	74-6 990	75-6 990	76-7 990
80-6 27 C.	56-8 990	57-8 990	58-9 990	59-9 990	60-9 990	61-9 990	63 989	64 989	65 989	66 989	80-6 27 C.	67-1 989	68-1 989	69-2 989	70-2 989	71-2 989	72-2 989	73-3 989	74-3 989	75-3 989	76-3 989
82-4 28 C.	56-4 989	57-5 989	58-5 989	59-5 989	60-6 989	61-6 989	62-6 989	63-7 989	64-7 989	65-7 989	82-4 28 C.	66-8 988	67-8 988	68-8 988	69-9 988	70-9 988	71-9 988	73 988	74 988	75 988	76 988
84-2 29 C.	56 988	57-1 988	58-1 988	59-2 988	60-2 988	61-2 988	62-3 988	63-3 988	64-3 988	65-4 988	84-2 29 C.	66-4 988	67-4 987	68-5 987	69-5 987	70-6 987	71-6 987	72-6 987	73-7 987	74-7 987	75-7 987
86-0 30 C.	55-7 987	56-7 987	57-8 987	58-8 987	59-9 987	60-9 987	61-9 987	63 987	64 987	65 987	86-0 30 C.	66-1 987	67-1 987	68-2 986	69-2 986	70-3 986	71-3 986	72-3 986	73-3 986	74-4 986	75-4 986

ALCOHOLOMETRY.

ALCOHOLOMETRY.

TABLE I.—Concluded.

Temp. Fahr.	Observed Percentage of the Alcolometer.										Temp. Fahr.	Observed Percentage of the Alcolometer.									
	81 p. c.	82 p. c.	83 p. c.	84 p. c.	85 p. c.	86 p. c.	87 p. c.	88 p. c.	89 p. c.	90 p. c.		91 p. c.	92 p. c.	93 p. c.	94 p. c.	95 p. c.	96 p. c.	97 p. c.	98 p. c.	99 p. c.	100 p. c.
32-0 0° C.	85-2 1014	86-2 1014	87-1 1014	88 1014	88-9 1014	89-9 1015	90-8 1015	91-7 1015	92-6 1015	93-6 1015	32-0 0° C.	94-5 1015	95-3 1015	96-2 1015	97-1 1015	98 1015	98-8 1015	99-7 1016			
33-8 1 C.	85 1013	85-9 1013	86-8 1013	87-8 1013	88-7 1013	89-6 1014	90-5 1014	91-5 1014	92-4 1014	93-3 1014	33-8 1 C.	94-3 1014	95-1 1014	96 1014	96-9 1014	97-8 1014	98-6 1014	99-5 1014			
35-6 2 C.	84-7 1012	85-6 1012	86-6 1012	87-5 1012	88-5 1012	89-4 1013	90-3 1013	91-2 1013	92-2 1013	93-1 1013	35-6 2 C.	94 1013	94-9 1013	95-8 1013	96-7 1013	97-6 1013	98-5 1013	99-3 1014			
37-4 3 C.	84-4 1011	85-4 1011	86-3 1011	87-3 1011	88-2 1011	89-2 1012	90-1 1012	91 1012	91-9 1012	92-9 1012	37-4 3 C.	93-8 1012	94-7 1012	95-6 1012	96-5 1012	97-4 1012	98-3 1012	99-2 1012	1012		
39-2 4 C.	84-2 1011	85-1 1011	86-1 1011	87 1011	87-9 1011	88-9 1011	89-8 1011	90-8 1011	91-7 1011	92-7 1011	39-2 4 C.	93-6 1011	94-5 1011	95-4 1011	96-3 1011	97-2 1011	98-1 1011	99 1011	99-9 1011		
41-0 5 C.	83-9 1010	84-8 1010	85-8 1010	86-7 1010	87-7 1010	88-6 1010	89-6 1010	90-5 1010	91-5 1010	92-4 1010	41-0 5 C.	93-4 1010	94-3 1010	95-2 1010	96-1 1010	97 1010	97-9 1010	98-8 1010	99-7 1010		
42-8 6 C.	83-6 1009	84-5 1009	85-5 1009	86-5 1009	87-4 1009	88-4 1009	89-3 1009	90-2 1009	91-2 1009	92-2 1009	42-8 6 C.	93-1 1009	94-1 1009	95 1009	95-9 1009	96-8 1009	97-8 1009	98-7 1009	99-6 1009		
44-6 7 C.	83-3 1008	84-2 1008	85-2 1008	86-2 1008	87-2 1008	88-1 1008	89-1 1008	90 1008	91 1008	91-9 1008	44-6 7 C.	92-9 1008	93-9 1008	94-8 1008	95-7 1008	96-6 1008	97-6 1008	98-5 1008	99-4 1008		
46-4 8 C.	83 1007	84 1007	85 1007	85-9 1007	86-9 1007	87-9 1007	88-8 1007	89-8 1007	90-7 1007	91-7 1007	46-4 8 C.	92-7 1007	93-6 1007	94-6 1007	95-5 1007	96-4 1007	97-4 1007	98-3 1007	99-2 1007	1007	
48-2 9 C.	82-7 1006	83-7 1006	84-7 1006	85-7 1006	86-6 1006	87-6 1006	88-6 1006	89-5 1006	90-5 1006	91-5 1006	48-2 9 C.	92-5 1006	93-4 1006	94-4 1006	95-3 1006	96-2 1006	97-2 1006	98-1 1006	99-1 1006	100 1006	
50-0 10 C.	82-4 1005	83-4 1005	84-4 1005	85-4 1005	86-4 1005	87-4 1005	88-3 1005	89-3 1005	90-2 1005	91-2 1005	50-0 10 C.	92-2 1005	93-2 1005	94-2 1005	95-1 1005	96 1005	97 1005	98 1005	98-9 1005	99-9 1005	
51-8 11 C.	82-2 1004	83-1 1004	84-1 1004	85-1 1004	86-1 1004	87-1 1004	88 1004	89 1004	90 1004	91 1004	51-8 11 C.	92 1004	92-9 1004	93-9 1004	94-9 1004	95-8 1004	96-8 1004	97-8 1004	98-7 1004	99-7 1004	
53-6 12 C.	81-9 1003	82-9 1003	83-9 1003	84-8 1003	85-8 1003	86-8 1003	87-8 1003	88-7 1003	89-7 1003	90-7 1003	53-6 12 C.	91-7 1003	92-7 1003	93-7 1003	94-7 1003	95-6 1003	96-6 1003	97-6 1003	98-5 1003	99-5 1003	
55-4 13 C.	81-6 1002	82-6 1002	83-6 1002	84-6 1002	85-5 1002	86-5 1002	87-5 1002	88-5 1002	89-5 1002	90-5 1002	55-4 13 C.	91-5 1002	92-5 1002	93-5 1002	94-4 1002	95-4 1002	96-4 1002	97-4 1002	98-4 1002	99-3 1002	
57-2 14 C.	81-3 1001	82-3 1001	83-3 1001	84-3 1001	85-3 1001	86-3 1001	87-3 1001	88-2 1001	89-2 1001	90-2 1001	57-2 14 C.	91-2 1001	92-2 1001	93-2 1001	94-2 1001	95-2 1001	96-2 1001	97-2 1001	98-2 1001	99-2 1001	
59-0 15 C.	81 1000	82 1000	83 1000	84 1000	85 1000	86 1000	87 1000	88 1000	89 1000	90 1000	59-0 15 C.	91 1000	92 1000	93 1000	94 1000	95 1000	96 1000	97 1000	98 1000	99 1000	100 1000
60-8 16 C.	80-7 999	81-7 999	82-7 999	83-7 999	84-7 999	85-7 999	86-7 999	87-7 999	88-7 999	89-7 999	60-8 16 C.	90-8 999	91-8 999	92-8 999	93-8 999	94-8 999	95-8 999	96-8 999	97-8 999	98-8 999	99-8 999
62-6 17 C.	80-4 998	81-4 998	82-4 998	83-4 998	84-4 998	85-4 998	86-4 998	87-4 998	88-4 998	89-4 998	62-6 17 C.	90-5 998	91-5 998	92-6 998	93-6 998	94-6 998	95-6 998	96-6 998	97-6 998	98-7 998	99-7 998
64-4 18 C.	80-1 997	81-1 997	82-1 997	83-1 997	84-1 997	85-2 997	86-2 997	87-2 997	88-2 997	89-2 997	64-4 18 C.	90-2 997	91-3 997	92-3 997	93-3 997	94-3 997	95-4 997	96-4 997	97-4 997	98-5 997	99-5 997
66-2 19 C.	79-8 996	80-8 996	81-9 996	82-9 996	83-9 996	84-9 996	85-9 996	86-9 996	87-9 996	88-9 996	66-2 19 C.	90 996	91-1 996	92-1 996	93-1 996	94-1 996	95-2 996	96-2 996	97-3 996	98-3 996	99-3 996
68-0 20 C.	79-5 995	80-5 995	81-6 995	82-6 995	83-6 995	84-6 995	85-6 995	86-6 995	87-7 995	88-7 995	68-0 20 C.	89-7 995	90-8 995	91-8 995	92-9 995	93-9 995	95 995	96 995	97-1 995	98-1 995	99-1 995
69-8 21 C.	79-2 994	80-2 994	81-3 994	82-3 994	83-3 994	84-3 994	85-3 994	86-4 994	87-4 994	88-4 994	69-8 21 C.	89-5 994	90-5 994	91-6 994	92-6 994	93-7 994	94-7 994	95-8 994	96-9 994	97-9 994	99 994
71-6 22 C.	78-9 993	79-9 993	81 993	82 993	83 993	84 993	85 993	86-1 993	87-1 993	88-2 993	71-6 22 C.	89-2 993	90-2 993	91-3 993	92-4 993	93-4 993	94-5 993	95-6 993	96-7 993	97-7 993	98-8 993
73-4 23 C.	78-6 992	79-6 992	80-7 992	81-7 992	82-7 992	83-8 992	84-8 992	85-8 992	86-8 992	87-9 992	73-4 23 C.	89 992	90 992	91-1 992	92-1 992	93-2 992	94-3 992	95-4 992	96-5 992	97-5 992	98-6 992
75-2 24 C.	78-3 991	79-3 991	80-4 991	81-4 991	82-4 991	83-5 991	84-5 991	85-5 991	86-5 991	87-6 991	75-2 24 C.	88-7 991	89-7 991	90-8 991	91-9 991	93 991	94-1 991	95-2 991	96-2 991	97-3 991	98-4 991
77-0 25 C.	78 991	79 991	80-1 990	81-1 990	82-2 990	83-2 990	84-2 990	85-2 990	86-3 990	87-4 990	77-0 25 C.	88-4 990	89-5 990	90-6 990	91-6 990	92-7 990	93-8 990	94-9 990	96 990	97-1 990	98-2 990
78-8 26 C.	77-7 990	78-7 989	79-8 989	80-8 989	81-8 989	82-9 989	83-9 989	84-9 989	86 989	87-1 989	78-8 26 C.	88-2 989	89-2 989	90-3 989	91-4 989	92-5 989	93-6 989	94-7 989	95-8 989	96-9 989	98-1 989
80-6 27 C.	77-4 989	78-4 989	79-5 989	80-5 989	81-5 989	82-6 989	83-6 989	84-7 989	85-7 989	86-8 989	80-6 27 C.	87-9 989	89 989	90-1 989	91-1 989	92-2 989	93-4 989	94-9 989	95-6 989	96-7 989	97-9 989
82-4 28 C.	77-1 988	78-1 988	79-2 987	80-2 987	81-2 987	82-3 987	83-3 987	84-4 987	85-4 987	86-5 987	82-4 28 C.	87-6 987	88-7 987	89-8 987	90-9 987	92 987	93-1 987	94-3 987	95-4 987	96-5 987	97-7 987
84-2 29 C.	76-7 987	77-8 987	78-9 986	79-9 986	80-9 986	82 986	83 986	84-1 986	85-1 986	86-2 986	84-2 29 C.	87-3 986	88-4 986	89-5 986	90-6 986	91-7 986	92-9 986	93-8 986	94-1 986	95-2 986	96-3 986
86-0 30 C.	76-4 986	77-5 986	78-6 986	79-6 986	80-6 985	81-7 985	82-7 985	83-8 985	84-9 985	86 985	86-0 30 C.	87-1 985	88-2 985	89-3 985	90-4 985	91-5 985	92-7 985	93-8 985	95 985	96-1 985	97-3 984

ALCOHOLOMETRY.

ALCOHOLOMETRY.

The second of Gay-Lussac's tables corresponds to Table VII. of Tralles, and gives directly, but less accurately, that which by the former table is only obtained by a calculation, viz., the richness or the per cent. by volume of the liquid at any temp. at which it is tested, from the observed per cent. Thus, if, as in the former example, the alcoholometer indicated 59 per

cent. in the liquid at 77°, the observed per cent., 59, is sought for in the upper horizontal column, and in the vertical column below it that number is then taken which is in the same horizontal column with the observed temp., 77°, in the left-hand column of temperatures. The number in this case is 55, or the liquid at the observed temp. of 77° contains 55 vols. of anhyd. alcohol.

TABLE II.

Alcoholometric Table of Gay-Lussac, to find directly the Percentage of Absolute Alcohol of a Liquid at any Temperature (its Richness) from the Observed Percentage at the same Temperature.

Temp.		Observed Percentage of the Alcoholometer.																			
Fahr.	Cent.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
32.0	0	1.3	2.4	3.4	4.4	5.4	6.5	7.5	8.6	9.7	10.9	12.2	13.4	14.7	16.1	17.5	19	20.4	21.7	23	24.3
33.8	1	—	—	—	—	—	—	—	—	—	—	—	13.4	14.7	16	17.3	18.7	20.1	21.4	22.7	24
35.6	2	—	—	—	—	—	—	—	—	—	—	—	13.4	14.7	16	17.2	18.6	19.9	21.2	22.4	23.7
37.4	3	—	—	—	—	—	—	—	—	—	—	—	13.3	14.6	15.9	17.1	18.3	19.7	20.9	22.1	23.4
39.2	4	—	—	—	—	—	—	—	—	—	—	—	13.3	14.5	15.8	16.9	18.1	19.4	20.7	21.9	23.1
41.0	5	1.4	2.5	3.5	4.5	5.5	6.6	7.7	8.7	9.8	10.9	12.1	13.2	14.4	15.7	16.8	18	19.2	20.5	21.6	22.8
42.8	6	—	—	—	—	—	—	—	—	—	—	—	13.1	14.3	15.6	16.7	17.8	19	20.3	21.4	22.5
44.6	7	—	—	—	—	—	—	—	—	—	—	—	13	14.2	15.4	16.6	17.7	18.8	20	21	22.1
46.4	8	—	—	—	—	—	—	—	—	—	—	—	13	14.1	15.3	16.4	17.5	18.6	19.7	20.7	21.8
48.2	9	—	—	—	—	—	—	—	—	—	—	—	12.9	14	15.1	16.2	17.3	18.4	19.5	20.5	21.6
50.0	10	1.4	2.4	3.4	4.5	5.5	6.5	7.5	8.5	9.5	10.6	11.7	12.7	13.8	14.9	16	17	18.1	19.2	20.2	21.3
51.8	11	1.3	2.4	3.4	4.4	5.4	6.4	7.4	8.4	9.4	10.5	11.6	12.6	13.6	14.7	15.8	16.8	17.9	19	20	21
53.6	12	1.2	2.3	3.3	4.3	5.3	6.3	7.3	8.3	9.3	10.4	11.5	12.5	13.5	14.6	15.6	16.6	17.6	18.7	19.7	20.7
55.4	13	1.2	2.2	3.2	4.2	5.2	6.2	7.2	8.2	9.2	10.3	11.4	12.4	13.4	14.4	15.4	16.4	17.4	18.5	19.5	20.5
57.2	14	1.1	2.1	3.1	4.1	5.1	6.1	7.1	8.1	9.1	10.2	11.2	12.2	13.2	14.2	15.2	16.2	17.2	18.2	19.2	20.2
59.0	15	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
60.8	16	0.9	1.9	2.9	3.9	4.9	5.9	6.9	7.9	8.9	9.9	10.9	11.9	12.9	13.9	14.9	15.9	16.9	17.8	18.7	19.7
62.6	17	0.8	1.8	2.8	3.8	4.8	5.8	6.8	7.8	8.8	9.8	10.8	11.7	12.7	13.7	14.7	15.6	16.6	17.5	18.4	19.4
64.4	18	0.7	1.7	2.7	3.7	4.7	5.7	6.7	7.7	8.7	9.7	10.7	11.6	12.5	13.5	14.5	15.4	16.3	17.3	18.2	19.1
66.2	19	0.6	1.6	2.6	3.6	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.4	12.4	13.3	14.3	15.2	16.1	17	17.9	18.8
68.0	20	0.5	1.5	2.4	3.4	4.4	5.4	6.4	7.3	8.3	9.3	10.3	11.2	12.2	13.1	14	14.9	15.8	16.7	17.6	18.5
69.8	21	0.4	1.4	2.3	3.3	4.3	5.2	6.2	7.1	8.1	9.1	10.1	11	11.9	12.8	13.7	14.6	15.5	16.4	17.3	18.2
71.6	22	0.3	1.3	2.2	3.2	4.1	5.1	6.1	7	7.9	8.9	9.9	10.8	11.7	12.6	13.5	14.4	15.3	16.2	17	17.9
73.4	23	0.1	1.1	2.1	3.1	4	4.9	5.9	6.8	7.8	8.7	9.7	10.6	11.5	12.4	13.3	14.1	15	15.9	16.7	17.6
75.2	24	0.0	1	1.9	2.9	3.8	4.8	5.8	6.7	7.6	8.5	9.5	10.4	11.3	12.2	13.1	13.9	14.8	15.7	16.5	17.4
77.0	25	—	0.8	1.7	2.7	3.6	4.6	5.5	6.5	7.4	8.3	9.3	10.2	11.1	12	12.8	13.6	14.5	15.4	16.2	17.1
78.8	26	—	0.7	1.6	2.6	3.5	4.4	5.4	6.3	7.2	8.1	9	9.9	10.8	11.7	12.6	13.4	14.2	15.1	15.9	16.7
80.6	27	—	0.5	1.5	2.4	3.3	4.3	5.2	6.1	7	7.9	8.8	9.7	10.6	11.5	12.3	13.1	13.9	14.8	15.6	16.4
82.4	28	—	0.3	1.3	2.2	3.1	4.1	5	5.9	6.8	7.7	8.6	9.5	10.3	11.2	12	12.8	13.6	14.4	15.2	16
84.2	29	—	0.1	1.1	2	2.9	3.9	4.8	5.7	6.6	7.5	8.4	9.2	10.1	11	11.7	12.5	13.3	14.1	14.9	15.7
86.0	30	—	0.0	0.9	1.9	2.8	3.7	4.6	5.5	6.4	7.3	8.1	9	9.8	10.7	11.5	12.3	13	13.8	14.6	15.4

Temp.		Observed Percentage of the Alcoholometer.																			
Fahr.	Cent.	21 p. c.	22 p. c.	23 p. c.	24 p. c.	25 p. c.	26 p. c.	27 p. c.	28 p. c.	29 p. c.	30 p. c.	31 p. c.	32 p. c.	33 p. c.	34 p. c.	35 p. c.	36 p. c.	37 p. c.	38 p. c.	39 p. c.	40 p. c.
32.0	0	25.7	27.1	28.5	29.9	31.1	32.3	33.4	34.5	35.6	36.6	37.6	38.6	39.6	40.6	41.5	42.5	43.5	44.4	45.4	46.4
33.8	1	25.4	26.8	28.1	29.4	30.6	31.8	32.9	34	35.1	36.1	37.1	38.1	39.1	40.1	41.2	42.2	43.1	44.1	45	46
35.6	2	25	26.4	27.6	28.9	30.2	31.4	32.5	33.5	34.6	35.6	36.7	37.7	38.7	39.7	40.7	41.7	42.7	43.7	44.6	45.5
37.4	3	24.7	26	27.3	28.6	29.8	31	32.1	33.1	34.1	35.2	36.2	37.3	38.3	39.3	40.3	41.3	42.3	43.2	44.2	45.2
39.2	4	24.4	25.7	26.9	28.1	29.3	30.6	31.6	32.7	33.7	34.7	35.7	36.7	37.7	38.7	39.8	40.8	41.8	42.8	43.8	44.8
41.0	5	24.1	25.3	26.5	27.7	28.9	30.1	31.2	32.3	33.3	34.3	35.3	36.3	37.3	38.3	39.3	40.3	41.4	42.4	43.4	44.3
42.8	6	23.7	25	26.1	27.3	28.5	29.7	30.8	31.8	32.8	33.8	34.9	35.9	36.9	37.9	38.9	39.9	40.9	41.9	42.9	43.9
44.6	7	23.4	24.7	25.8	27	28.1	29.3	30.3	31.3	32.3	33.3	34.3	35.4	36.4	37.4	38.4	39.4	40.4	41.4	42.4	43.4
46.4	8	23	24.2	25.4	26.6	27.7	28.9	29.9	30.9	31.9	32.9	33.9	34.9	35.9	36.9	38	39	40	41	42	43
48.2	9	22.7	23.9	25	26.2	27.3	28.5	29.5	30.5	31.5	32.5	33.5	34.5	35.5	36.5	37.5	38.6	39.6	40.6	41.6	42.6
50.0	10	22.4	23.5	24.6	25.8	26.9	28	29.1	30.1	31.1	32.1	33.1	34.1	35.1	36.1	37.1	38.1	39.1	40.1	41.1	42.1
51.8	11	22.1	23.2	24.3	25.4	26.5	27.7	28.7	29.7	30.7	31.7	32.7	33.7	34.7	35.7	36.7	37.7	38.7	39.7	40.7	41.7
53.6	12	21.8	22.9	24	25.1	26.1	27.2	28.2	29.2	30.2	31.2	32.2	33.2	34.3	35.3	36.3	37.3	38.3	39.3	40.3	41.3
55.4	13	21.5	22.6	23.7	24.7	25.7	26.8	27.8	28.8	29.8	30.8	31.8	32.8	33.8	34.8	35.8	36.8	37.8	38.8	39.8	40.8
57.2	14	21.2	22.3	23.3	24.3	25.3	26.4	27.4	28.4	29.4	30.4	31.4	32.4	33.4	34.4	35.4	36.4	37.4	38.4	39.4	40.4
59.0	15	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
60.8	16	20.7	21.7	22.7	23.7	24.7	25.7	26.6	27.6	28.6	29.6	30.6	31.6	32.5	33.5	34.5	35.5	36.5	37.5	38.5	39.5
62.6	17	20.4	21.4	22.4	23.4	24.4	25.4	26.3	27.3	28.2	29.2	30.2	31.2	32.1	33.1	34.1	35.1	36.1	37.1	38.1	39.1
64.4	18	20.1	21.1	22	23	24	25	25.9	26.9	27.8	28.8	29.8	30.8	31.7	32.6	33.6	34.6	35.6	36.6	37.6	38.6
66.2	19	19.8	20.8	21.7	22.7	23.6	24.6	25.5	26.4	27.3	28.3	29.3	30.3	31.2	32.2	33.2	34.2	35.2	36.2	37.2	38.2
68.0	20	19.5	20.5	21.4	22.4	23.3	24.3	25.2	26.1	27	27.9	28.9	29.9	30.8	31.8	32.8	33.8	34.8	35.8	36.8	37.8
69.8	21	19.1	20.1	21.1	22.1	22.9	23.9	24.8	25.6	26.6	27.5	28.5	29.5	30.4	31.4	32.4	33.4	34.4	35.4	36.4	37.4
71.6	22	18.8	19.8	20.7	21.6	22.5	23.5	24.3	25.2	26.2	27.1	28.1	29.1	30	31	32	33	34	35	36	36.9
73.4	23	18.5	19.4	20.3	21.3	22.2	23.1	24	24.9	25.8	26.7	27.7	28.7	29.6	30.6	31.6	32.6	33.5	34.5	35.5	36.5
75.2	24	18.2	19.1	20	21	21.8	22.7	23.6	24.5	25.4	26.3	27.3	28.3	29.2	30.2	31.1	32.1	33.1	34.1	35.1	36.1
77.0	25	17.9	18.8	19.7	20.6	21.5	22.4	23.2	24.2	25.1	26	26.9	27.9	28.8	29.7	30.7	31.7	32.7	33.7	34.7	35.7
78.8	26	17.6	18.5	19.4	20.3	21.2	22.1	22.9	23.8	24.7	25.6	26.5	27.5	28.4	29.3	30.3	31.3	32.3	33.3	34.3	35.3
80.6	27	17.3	18.2	19.1	20	20.8	21.7	22.6	23.5	24.3	25.2	26.1	27.1	27.9	28.9	29.9	30.9	31.9	32.9	33.9	34.9
82.4	28	16.9	17.9	18.8	19.6	20.5	21.4	22.2	23.1	23.9	24.8	25.7	26.6	27.5	28.5	29.5	30.5	31.5	32.5	33.5	34.4
84.2	29	16.6	17.7	18.4	19.3	20.2	21	21.8	22.7	23.6	24.4	25.2	26.2	27.1	28.1	29.1	30.1	31.1	32.1	33.1	34
86.0	30	16.3	17.2	18.1	19	19.8	20.7	21.5	22.4	23.2	24	24.9	25.8	26.7	27.7	28.7	29.7	30.7	31.6	32.6	33.5

ALCOHOLOMETRY.

ALCOHOLOMETRY.

TABLE II.—Continued.

Temp.		Observed Percentage of the Alcolometer.																			
		41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Fahr.	Cent.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
32.0	0	47.4	48.4	49.3	50.3	51.3	52.3	53.2	54.1	55.1	56.1	57.1	58	59	59.9	60.9	61.9	62.9	63.9	64.9	65.8
33.8	1	47	48	48.9	49.9	50.8	51.8	52.8	53.7	54.7	55.7	56.7	57.6	58.6	59.6	60.6	61.6	62.6	63.6	64.5	65.5
35.6	2	46.5	47.5	48.5	49.5	50.4	51.4	52.3	53.3	54.3	55.3	56.3	57.2	58.2	59.2	60.2	61.2	62.1	63.1	64.1	65.1
37.4	3	46.2	47.1	48.1	49	50	51	52	52.9	53.9	54.8	55.8	56.8	57.8	58.8	59.8	60.8	61.7	62.7	63.7	64.7
39.2	4	45.8	46.7	47.7	48.7	49.6	50.6	51.5	52.5	53.5	54.5	55.5	56.5	57.4	58.4	59.4	60.3	61.3	62.3	63.3	64.3
41.0	5	45.3	46.2	47.2	48.2	49.2	50.2	51.1	52.1	53.1	54	55	56	57	58	59	60	60.9	61.9	62.9	63.9
42.8	6	44.9	45.8	46.8	47.8	48.8	49.8	50.8	51.7	52.7	53.7	54.7	55.6	56.6	57.5	58.5	59.5	60.5	61.5	62.5	63.5
44.6	7	44.4	45.4	46.4	47.4	48.4	49.4	50.4	51.3	52.3	53.2	54.2	55.2	56.2	57.1	58.1	59.1	60.1	61.1	62.1	63.1
46.4	8	44	45	46	47	47.9	48.9	49.9	50.9	51.9	52.9	53.9	54.9	55.8	56.8	57.8	58.8	59.8	60.8	61.8	62.8
48.2	9	43.6	44.6	45.6	46.6	47.5	48.5	49.5	50.5	51.5	52.5	53.5	54.5	55.4	56.4	57.4	58.4	59.4	60.4	61.4	62.4
50.0	10	43.1	44.1	45.1	46.1	47.1	48.1	49.1	50.1	51.1	52	53	54	55	56	57	58	59	60	61	62
51.8	11	42.7	43.7	44.7	45.7	46.7	47.7	48.7	49.7	50.7	51.7	52.7	53.7	54.6	55.6	56.6	57.6	58.6	59.6	60.6	61.6
53.6	12	42.3	43.3	44.3	45.3	46.3	47.3	48.3	49.3	50.3	51.2	52.2	53.2	54.2	55.2	56.2	57.2	58.2	59.2	60.2	61.2
55.4	13	41.9	42.9	43.9	44.9	45.9	46.9	47.9	48.9	49.9	50.9	51.9	52.8	53.8	54.8	55.8	56.8	57.8	58.8	59.8	60.8
57.2	14	41.4	42.4	43.4	44.4	45.4	46.4	47.4	48.4	49.4	50.4	51.4	52.4	53.4	54.4	55.4	56.4	57.4	58.4	59.4	60.4
59.0	15	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
60.8	16	40.6	41.6	42.6	43.6	44.6	45.6	46.6	47.6	48.6	49.6	50.6	51.6	52.6	53.6	54.6	55.6	56.6	57.6	58.6	59.6
62.6	17	40.1	41.1	42.1	43.1	44.1	45.2	46.2	47.2	48.2	49.2	50.2	51.2	52.2	53.2	54.2	55.2	56.2	57.2	58.2	59.2
64.4	18	39.7	40.7	41.7	42.7	43.7	44.8	45.8	46.8	47.8	48.8	49.8	50.8	51.8	52.8	53.8	54.8	55.8	56.8	57.8	58.8
66.2	19	39.3	40.3	41.3	42.4	43.4	44.4	45.4	46.4	47.4	48.4	49.4	50.4	51.4	52.4	53.4	54.4	55.4	56.4	57.4	58.4
68.0	20	38.9	39.9	40.9	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
69.8	21	38.4	39.4	40.4	41.5	42.5	43.5	44.6	45.6	46.6	47.6	48.6	49.6	50.6	51.6	52.6	53.6	54.6	55.6	56.6	57.6
71.6	22	38	39	40	41.1	42.1	43.1	44.1	45.1	46.1	47.1	48.1	49.1	50.1	51.1	52.2	53.2	54.2	55.2	56.2	57.2
73.4	23	37.6	38.6	39.6	40.6	41.6	42.6	43.6	44.6	45.7	46.7	47.7	48.8	49.8	50.8	51.8	52.8	53.8	54.8	55.8	56.8
75.2	24	37.2	38.2	39.2	40.2	41.2	42.2	43.3	44.3	45.3	46.3	47.3	48.4	49.4	50.4	51.4	52.4	53.4	54.4	55.4	56.4
77.0	25	36.7	37.7	38.7	39.8	40.8	41.9	42.9	43.9	44.9	46	47	48	49	50	51	52	53	54	55	56
78.8	26	36.3	37.3	38.3	39.4	40.4	41.5	42.5	43.5	44.5	45.5	46.5	47.5	48.5	49.5	50.5	51.5	52.5	53.5	54.5	55.6
80.6	27	35.9	36.9	37.9	39	40	41.1	42.1	43.1	44.1	45.1	46.1	47.1	48.1	49.1	50.1	51.2	52.2	53.2	54.2	55.2
82.4	28	35.4	36.5	37.5	38.6	39.6	40.6	41.6	42.6	43.7	44.7	45.7	46.7	47.7	48.7	49.8	50.8	51.8	52.8	53.8	54.8
84.2	29	35	36	37.1	38.1	39.1	40.2	41.2	42.2	43.3	44.3	45.3	46.3	47.3	48.4	49.4	50.4	51.4	52.4	53.4	54.4
86.0	30	34.6	35.6	36.6	37.7	38.7	39.8	40.8	41.8	42.8	43.8	44.9	45.9	47	48	49	50	51	52	53	54

Temp.		Observed Percentage of the Alcolometer.																			
		61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Fahr.	Cent.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
32.0	0	66.8	67.8	68.8	69.8	70.8	71.7	72.7	73.7	74.7	75.7	76.6	77.6	78.6	79.6	80.6	81.6	82.6	83.6	84.5	85.5
33.8	1	66.5	67.5	68.5	69.4	70.4	71.3	72.3	73.3	74.3	75.3	76.2	77.2	78.2	79.2	80.2	81.2	82.2	83.2	84.2	85.1
35.6	2	66.1	67.1	68.1	69.1	70.1	71.1	71.9	72.9	73.9	74.9	75.9	76.9	77.9	78.9	79.9	80.9	81.9	82.9	83.8	84.7
37.4	3	65.6	66.6	67.6	68.6	69.6	70.6	71.6	72.6	73.6	74.5	75.5	76.5	77.5	78.5	79.5	80.5	81.5	82.5	83.4	84.4
39.2	4	65.3	66.3	67.3	68.3	69.3	70.2	71.2	72.2	73.2	74.1	75.1	76.1	77.1	78.1	79.1	80.1	81.1	82.1	83	84
41.0	5	64.9	65.9	66.9	67.9	68.9	69.8	70.8	71.8	72.8	73.8	74.8	75.7	76.7	77.7	78.7	79.7	80.7	81.7	82.7	83.7
42.8	6	64.5	65.5	66.5	67.5	68.5	69.5	70.5	71.5	72.5	73.4	74.4	75.3	76.3	77.3	78.3	79.3	80.3	81.3	82.3	83.3
44.6	7	64.1	65.1	66.1	67.1	68.1	69.1	70.1	71.1	72	73	74	75	76	77	78	79	80	81	82	82.9
46.4	8	63.8	64.8	65.8	66.8	67.7	68.7	69.7	70.6	71.6	72.6	73.6	74.6	75.6	76.6	77.6	78.6	79.6	80.6	81.6	82.6
48.2	9	63.4	64.4	65.4	66.4	67.3	68.3	69.3	70.3	71.3	72.3	73.3	74.2	75.2	76.2	77.2	78.2	79.2	80.2	81.2	82.2
50.0	10	63	64	65	66	67	67.9	68.9	69.9	70.9	71.9	72.9	73.9	74.9	75.9	76.9	77.9	78.9	79.9	80.9	81.9
51.8	11	62.6	63.6	64.6	65.6	66.6	67.6	68.6	69.6	70.6	71.6	72.6	73.5	74.5	75.5	76.5	77.5	78.5	79.5	80.5	81.5
53.6	12	62.2	63.2	64.2	65.2	66.2	67.2	68.2	69.2	70.2	71.2	72.2	73.1	74.1	75.1	76.1	77.1	78.1	79.1	80.1	81.1
55.4	13	61.8	62.8	63.8	64.8	65.8	66.8	67.8	68.8	69.8	70.8	71.8	72.8	73.8	74.8	75.8	76.8	77.8	78.8	79.8	80.8
57.2	14	61.4	62.4	63.4	64.4	65.4	66.4	67.4	68.4	69.4	70.4	71.4	72.4	73.4	74.4	75.4	76.4	77.4	78.4	79.4	80.4
59.0	15	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
60.8	16	60.6	61.6	62.6	63.6	64.6	65.6	66.6	67.6	68.6	69.6	70.6	71.6	72.6	73.6	74.6	75.6	76.6	77.6	78.6	79.6
62.6	17	60.2	61.2	62.2	63.2	64.2	65.2	66.2	67.2	68.2	69.2	70.2	71.2	72.2	73.2	74.2	75.2	76.2	77.2	78.2	79.2
64.4	18	59.8	60.8	61.8	62.8	63.8	64.8	65.8	66.8	67.8	68.8	69.8	70.8	71.8	72.8	73.8	74.8	75.8	76.8	77.8	78.8
66.2	19	59.4	60.4	61.4	62.5	63.5	64.5	65.5	66.5	67.5	68.5	69.5	70.5	71.5	72.5	73.5	74.5	75.5	76.5	77.5	78.5
68.0	20	59	60	61	62	63	64	65.1	66.1	67.1	68.1	69.1	70.1	71.1	72.1	73.1	74.1	75.1	76.1	77.1	78.1
69.8	21	58.6	59.6	60.7	61.7	62.7	63.7	64.7	65.7	66.7	67.7	68.7	69.7	70.7	71.7	72.7	73.7	74.7	75.8	76.8	77.8
71.6	22	58.2	59.2	60.3	61.3	62.3	63.3	64.3	65.3	66.3	67.3	68.3	69.3	70.3	71.3	72.3	73.3	74.3	75.4	76.4	77.4
73.4	23	57.8	58.8	59.8	60.9	61.9	62.9	63.9	64.9	65.9	66.9	67.9	68.9	70	71	72	73	74	75	76	77
75.2	24	57.4	58.4	59.4	60.5	61.5	62.5	63.5	64.5	65.5	66.5	67.5	68.5	69.6	70.6	71.6	72.6	73.6	74.6	75.6	76.6
77.0	25	57	58	59	60.1	61.1	62.1	63.1	64.1	65.1	66.1	67.1	68.1	69.2	70.2	71.2	72.2	73.2	74.2	75.3	76.3
78.8	26	56.6	57.6	58.6	59.6	60.7	61.7	62.7	63.7	64.7	65.7	66.7	67.7	68.8	69.8	70.8	71.8	72.8	73.8	74.8	75.9
80.6	27	56.2	57.2	58.3	59.3	60.3	61.3	62.3	63.3	64.3	65.3	66.3	67.3	68.4	69.4	70.4	71.4	72.4	73.4	74.4	75.5
82.4	28	55.8	56.8	57.8	58.8	59.9	60.9	61.9	62.9	63.9	64.9	66	67	68	69.1	70.1	71.1	72.1	73.1	74.1	75.1
84.2	29	55.4	56.4	57.4	58.5	59.5	60.5	61.5	62.5	63.5	64.5	65.6	66.6	67.7	68.7	69.7	70.7	71.7	72.7	73.7	74.7
86.0	30	55	56	57	58.1	59.1	60.1	61.1	62.1	63.1	64.1	65.2	66.2	67.3	68.3	69.3	70.3	71.3	72.3	73.3	74.3

TABLE II.—*Concluded.*

Temp.		Observed Percentage of the Alcoholometer.																			
Fahr.	Cent.	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
		p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
50.0	10	82.8	83.8	84.8	85.8	86.8	87.8	88.7	89.7	90.7	91.7	92.7	93.7	94.7	95.6	96.5	97.5	98.5	99.4	100.4	
51.8	11	82.5	83.4	84.4	85.4	86.4	87.4	88.4	89.4	90.4	91.4	92.4	93.3	94.3	95.3	96.2	97.2	98.2	99.1	100.1	
53.6	12	82.1	83.1	84.1	85	86	87	88	89	90	91	92	93	94	95	95.9	96.9	97.9	98.8	99.8	
55.4	13	81.8	82.8	83.8	84.8	85.7	86.7	87.7	88.7	89.7	90.7	91.7	92.7	93.7	94.6	95.6	96.6	97.6	98.6	99.5	
57.2	14	81.4	82.4	83.4	84.4	85.4	86.4	87.4	88.3	89.3	90.3	91.3	92.3	93.3	94.3	95.3	96.3	97.3	98.3	99.3	
59.0	15	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
60.8	16	80.6	81.6	82.6	83.6	84.6	85.6	86.6	87.6	88.6	89.6	90.7	91.7	92.7	93.7	94.7	95.7	96.7	97.7	98.7	99.7
62.6	17	80.2	81.2	82.2	83.2	84.2	85.2	86.2	87.2	88.2	89.3	90.3	91.3	92.4	93.4	94.4	95.4	96.4	97.4	98.5	99.5
64.4	18	79.9	80.9	81.9	82.9	83.9	84.9	85.9	86.9	87.9	88.9	89.9	91	92	93	94	95.1	96.1	97.1	98.2	99.2
66.2	19	79.5	80.5	81.6	82.6	83.6	84.6	85.6	86.6	87.6	88.6	89.6	90.7	91.7	92.7	93.7	94.8	95.8	96.9	97.9	98.9
68.0	20	79.1	80.1	81.2	82.2	83.2	84.2	85.2	86.2	87.2	88.2	89.2	90.3	91.3	92.4	93.4	94.5	95.5	96.6	97.6	98.6
69.8	21	78.7	79.7	80.8	81.8	82.8	83.8	84.8	85.9	86.9	87.9	88.9	90	91	92	93.1	94.1	95.2	96.3	97.3	98.4
71.6	22	78.4	79.4	80.4	81.4	82.4	83.4	84.4	85.5	86.5	87.6	88.6	89.6	90.7	91.8	92.8	93.9	94.9	96	97	98.1
73.4	23	78	79	80.1	81.1	82.1	83.1	84.1	85.1	86.1	87.2	88.3	89.3	90.4	91.4	92.4	93.5	94.6	95.7	96.7	97.8
75.2	24	77.6	78.6	79.7	80.7	81.7	82.7	83.7	84.7	85.7	86.8	87.9	88.9	90	91.1	92.1	93.2	94.3	95.3	96.4	97.5
77.0	25	77.3	78.3	79.3	80.3	81.3	82.3	83.4	84.4	85.4	86.5	87.5	88.6	89.7	90.7	91.8	92.9	93.9	95	96.1	97.2
78.8	26	76.9	77.9	78.9	79.9	80.9	81.9	82.9	84	85	86.1	87.2	88.2	89.3	90.4	91.5	92.5	93.6	94.7	95.8	97
80.6	27	76.5	77.5	78.5	79.5	80.5	81.6	82.6	83.6	84.7	85.7	86.8	87.9	89	90	91.1	92.2	93.3	94.4	95.5	96.7
82.4	28	76.1	77.1	78.2	79.2	80.2	81.3	82.3	83.3	84.3	85.4	86.5	87.5	88.6	89.7	90.8	91.9	93	94.1	95.2	96.4
84.2	29	75.7	76.8	77.8	78.8	79.8	80.9	81.9	83	84	85	86.1	87.2	88.2	89.3	90.4	91.6	92.7	93.8	94.9	96.1
86.0	30	75.3	76.4	77.4	78.4	79.4	80.5	81.5	82.6	83.6	84.7	85.8	86.9	87.9	89	90.1	91.2	92.4	93.5	94.6	95.8

Tralles's and Gay-Lussac's alcoholometers have been adopted in different countries: the first in Prussia, the latter in France and Sweden. They both give the per cent. of alcohol in

volume. If it be desired to know the *per cent. by weight*, it may be ascertained from the *percentage in volume of the liquid at 60°*, by the following

Table of Comparison between the Per Cent. of Alcoh. by Vol. at 60° (Tralles's), and Per Cent. by Weight.

Per Cent.		Per Cent.		Per Cent.		Per Cent.	
By Vol.	By Weight.	By Vol.	By Weight.	By Weight.	By Vol.	By Weight.	By Vol.
0	0	55	47.29	0	0	55	63.97
5	4.00	60	52.20	5	6.25	60	68.97
10	8.05	65	57.25	10	12.42	65	73.79
15	12.15	70	62.51	15	18.52	70	78.40
20	16.28	75	67.93	20	24.57	75	82.80
25	20.46	80	73.59	25	30.55	80	86.97
30	24.69	85	79.50	30	36.45	85	90.88
35	28.99	90	85.75	35	42.25	90	94.46
40	33.39	95	92.46	40	47.92	95	97.61
45	37.90	100	100.00	45	53.43	100	100.00
50	42.52			50	58.79		

Or it may be ascertained by calculation from the *percentage by volume of the liquid at any temperature*, by multiplying the percentage by vol. by the spec. grav. of the anhydrous alcohol of

the normal temperature, that is, 0.7939, when ascertained by Tralles's, or 0.7947 by Gay-Lussac's, and dividing the product by the spec. grav. of the liquid. We here subjoin a

Table by Lowitz, giving the Per Cent. of Absolute Alcohol by Weight, from the Spec. Grav. at 68°.

Per ct. of alcohol by weight.	Specific gravity at 68°.	Per ct. of alcohol by weight.	Specific gravity at 68°.	Per ct. of alcohol by weight.	Specific gravity at 68°.	Per ct. of alcohol by weight.	Specific gravity at 68°.	Per ct. of alcohol by weight.	Specific gravity at 68°.	Per ct. of alcohol by weight.	Specific gravity at 68°.	Per ct. of alcohol by weight.	Specific gravity at 68°.	Per ct. of alcohol by weight.	Specific gravity at 68°.
100	791	87	826	74	859	61	889	48	919	35	946	23	968	11	986
99	794	86	828	73	861	60	892	47	921	34	948	22	970	10	987
98	797	85	831	72	863	59	894	46	923	33	950	21	971	9	988
97	800	84	834	71	866	58	896	45	925	32	952	20	973	8	989
96	803	83	836	70	868	57	899	44	927	31	954	19	974	7	991
95	805	82	839	69	870	56	901	43	930	30	956	18	976	6	992
94	808	81	842	68	872	55	903	42	932	29	957	17	977	5	994
93	811	80	844	67	875	54	905	41	934	28	959	16	978	4	995
92	813	79	847	66	877	53	907	40	936	27	961	15	980	3	997
91	816	78	849	65	880	52	909	39	938	26	963	14	981	2	998
90	818	77	851	64	882	51	912	38	940	25	965	13	983	1	999
89	821	76	853	63	885	50	914	37	942	24	966	12	985	0	1000
88	823	75	856	62	887	49	917	36	944						

When a scale of per cent. by weight is added to Tralles's alcoholometer, it sometimes bears the name of Richter's scale, in which, as in

other cases, is often meant only per cent. by weight, without reference to his original alcoholometer, and which is less accurate.

In England, the strength of spirit, for the collection of revenue, is determined by Sikes's hydrometer, which is made of brass, with ballast weights, and does not indicate directly the spec. grav. or the amount of absolute alcohol, but the amount of spirit of a certain strength, which is called *proof spirit*. The term *proof spirit* originated from a rude method formerly practised of ascertaining the strength of spirit by pouring it into a dish on gunpowder and inflaming it; which was called the *proof*. If, at the end of the combustion, the gunpowder took fire, the spirit was said to be *above or over proof*, if not, it was said to be *below or under proof*. But as this is a very uncertain test, since the same spirit, which, in a smaller quantity, may set fire to the gunpowder, will, when used in larger quantity, leave so much water behind as to prevent the ignition; the *strength of proof spirit* has been fixed by act of parliament to be such, that at 51° thirteen vols. of it should be equal in weight to twelve vols. of water. According to this definition, the spec. grav. of proof spirit is .9186 at 60°, and it contains 57.27 per cent. absolute alcohol by vol., or 49.50 by weight. The strength of spirit is then indicated by a certain number over or under proof, indicating the number of vols. which are to be added to or subtracted from 100 vols. of the spirit, in order to render it proof spirit; thus by the expression *ten over proof* is meant, that 100 galls. of the spirit would stand the addition of water till it formed 110 galls., which would have the strength of proof spirit; and *ten below proof* means, that so much water is to be abstracted from 100 vols. as would diminish it 10 vols. in order to render it proof spirit; or, that 100 galls. of it contain 90 galls. of proof spirit.

The following table, extracted from a work by Gutteridge, gives a comparison between the indications of Sikes's hydrometer and the spec. gravs. corresponding to them; but Pereira (*Mut. Med.* vol. i. p. 316) expresses doubts of its perfect correctness.

*Sikes's Hydrometer.*Sp. gr. at
60° F.

70 per ct.	0.8095
64	0.8221
63.1	0.8238
62	0.8259
61.1	0.8277
60	0.8298
59.1	0.8315
58	0.8336
57.1	0.8354
56	0.8376
55.9	0.8379
55.7	0.8383
55.0	0.8396
54.1	0.8413
50.1	0.8482
43.1	0.8597
25	0.8869
11.1	0.9060

Over proof.

*Sikes's Hydrometer.*Sp. gr. at
60° F.

Proof.	0.9200
5 per ct.	0.9259
10	0.9318
11	0.9329
15.3	0.9376
17.1	0.9396
20	0.9426
22.3	0.9448
23.1	0.9456
25.1	0.9476
30.1	0.9522
40.1	0.9603
50.3	0.9673
60.4	0.9734
70.1	0.9790
80.4	0.9854
90.2	0.9922
100 (water).	1.0000

Under proof.

with a sliding rule and thermometer to make the correction for temperature. By aid of this, the strength of the spirit is indicated, as with Sikes's hydrometer, by a certain number above or below proof. The act of 15th April, 1835, determines the standard of proofs to be as follows: "If the liquor shall be hydrometer proof, or 100 (parts) spirits (spirit), and 100 parts water, it shall be marked as liquor of the fourth proof; if the liquor shall be 5° below hydrometer proof, it shall be marked as liquor of the third proof; if the liquor shall be 10° below hydrometer proof, it shall be marked as liquor of the second proof; if the liquor shall be 15° below hydrometer proof, it shall be marked as liquor of the first proof."

In regard to the strength of proof by Dica's hydrometer, which, in the above act, is defined by equal parts of spirit (abs. alcohol) and water; Ure, in his Dictionary, gives the spec. gravs. by his experiments of a few of the indications of Dica's hydrometer at 60°, as follows:

10 over proof on Dica's	corresponds to	Sp. Gr.
3½ " " " "		0.9085
Proof		0.9169
		0.9218

Spirit of this latter spec. grav. at 60° contains 55.76 per cent. alc. by vol. or 48.03 by weight.

We pass over other alcoholometers, some of which have been constructed with a view to avoid correction by table, by having two scales, the one movable, sliding over the other according to its corrections for temperature, but are not to be relied on with the same certainty as by the use of tables. Others have been constructed with a view to improve their accuracy by always immersing them to the same point of the stem (see *HYDROMETERS*), by different weights placed on a dish on the top of the stem; but the inconvenience of their use does not compensate for their greater accuracy.

Whenever the per cent. of alcohol by weight is known, the quantity of water by weight in the liquid is of course obtained by subtracting the percentage of alcohol from 100. Not so with per cent. by vol., since a contraction takes place by the mixtures of alcohol and water. A spirit of 49 per cent. by vol. does not therefore contain 51 vols. of water, but so much water as is necessary to make, with the 49 vols. of alcohol, 100 vols. of the mixture, which is more than 51 vols. water. The following table shows the different vols. of alcohol and water in 100 vols. of the mixture at 59°.

100 vols. spirit contain at 59°.		100 vols. spirit contain at 59°.	
Vol. of alcohol.	Vol. of water.	Vol. of alcohol.	Vol. of water.
100	0.00	45	58.64
95	6.18	40	63.44
90	11.94	35	68.14
85	17.47	30	72.72
80	22.87	25	77.24
75	28.19	20	81.72
70	33.14	15	86.20
65	38.615	10	90.72
60	43.73	5	95.31
55	48.77	0	100.00
50	53.745		

In Pennsylvania, "Dica's Liverpool patent hydrometer" is adopted by act of 15th April, 1835, for the inspection of domestic distilled liquors. It is made of copper, with a stem, pointed on its summit to receive brass poises, and is accompanied by a graduated ivory scale,

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Table of Gay-Lussac for Procuring a Weaker Alcohol of a certain Strength from a Stronger.

1000 vol. of alcohol of per cent. by vol.	Desired Strength of the Spirit. Percent. by Volume.														
	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
31	33														
32	67	32													
33	100	65	31												
34	134	97	63	30											
35	167	129	94	61	30										
36	201	162	126	91	59	29									
37	234	194	157	122	89	58	28								
38	268	227	189	153	119	86	56	27							
39	302	260	220	183	148	115	84	55	27						
40	335	292	252	214	178	144	112	82	53	26					
41	369	325	284	245	208	173	140	109	80	52	25				
42	403	358	315	275	238	202	169	137	107	78	51	25			
43	437	390	347	306	268	231	197	164	134	104	76	50	24		
44	471	423	379	337	298	261	225	192	160	130	102	75	49	24	
45	505	456	411	368	328	290	254	220	187	157	127	99	73	47	23
46	539	489	443	399	358	319	282	247	214	183	153	124	97	71	46
47	573	522	474	430	388	348	310	275	241	209	179	149	122	95	70
48	607	555	506	461	418	377	339	303	268	235	204	174	146	119	93
49	641	588	538	492	448	407	367	330	295	262	230	200	171	143	116
50	675	621	570	523	478	436	396	358	322	288	256	225	195	167	140
51	709	654	602	554	508	465	424	386	349	314	281	250	220	191	163
52	743	687	634	585	539	495	453	414	376	341	307	275	244	215	187
53	777	720	666	616	569	524	482	442	403	367	333	300	269	239	210
54	811	753	699	647	599	553	510	469	431	394	359	325	293	263	234
55	846	786	731	679	629	583	539	497	458	420	385	350	318	287	257
56	880	820	763	700	660	613	568	525	485	447	411	376	343	311	281
57	914	853	795	741	690	642	596	553	512	473	436	401	367	335	305
58	949	886	827	772	721	672	625	581	540	500	462	426	392	359	328
59	983	919	860	804	751	701	654	609	567	527	488	452	417	384	352
60	1017	953	892	835	781	731	683	637	594	553	514	477	442	408	375
61	1052	986	924	867	812	760	711	665	622	580	540	503	467	432	399
62	1086	1019	957	898	842	790	740	694	649	607	566	528	491	456	423
63	1121	1053	989	929	873	820	769	722	676	633	593	554	516	481	447
64	1155	1086	1022	961	904	850	798	750	704	660	619	579	541	505	471
65	1190	1120	1054	992	934	879	827	778	731	687	645	605	566	529	494
66	1224	1153	1086	1024	965	909	856	806	759	714	671	630	591	554	518
67	1259	1187	1119	1055	995	939	885	834	786	741	697	656	616	578	542
68	1293	1220	1151	1087	1026	969	914	863	814	767	723	681	641	603	566
69	1328	1254	1184	1118	1056	998	943	891	841	794	750	707	666	627	590
70	1363	1287	1216	1150	1087	1028	972	919	869	821	776	732	691	652	614
71	1397	1321	1249	1182	1118	1058	1001	948	897	848	802	758	716	676	638
72	1432	1354	1282	1213	1149	1088	1030	977	924	875	828	784	741	701	662
73	1467	1388	1314	1245	1180	1118	1060	1005	952	902	855	810	767	725	686
74	1502	1422	1347	1277	1211	1148	1089	1033	980	929	881	835	792	750	710
75	1536	1456	1380	1309	1241	1178	1118	1061	1008	956	908	861	817	775	734
76	1571	1489	1413	1340	1272	1208	1147	1089	1035	983	934	887	842	799	758
77	1606	1523	1445	1372	1303	1238	1177	1118	1063	1011	961	913	867	824	782
78	1641	1557	1478	1404	1334	1268	1206	1147	1091	1038	987	939	893	849	807
79	1676	1591	1511	1436	1365	1299	1235	1175	1119	1065	1014	965	918	873	831
80	1711	1625	1544	1468	1396	1329	1265	1204	1147	1092	1040	991	943	898	855
81	1746	1658	1577	1500	1427	1359	1294	1233	1175	1119	1067	1017	969	923	879
82	1781	1692	1610	1532	1458	1389	1323	1261	1203	1147	1093	1043	994	948	904
83	1816	1726	1643	1564	1489	1419	1353	1290	1231	1174	1120	1069	1020	973	928
84	1851	1760	1676	1596	1521	1450	1382	1319	1259	1201	1147	1095	1045	998	952
85	1886	1794	1709	1628	1552	1480	1412	1348	1287	1229	1173	1121	1071	1023	977
86	1921	1828	1742	1660	1583	1510	1442	1376	1315	1256	1200	1147	1096	1048	1001
87	1956	1863	1775	1692	1614	1541	1471	1405	1343	1284	1227	1173	1122	1073	1026
88	1992	1897	1808	1724	1645	1571	1501	1434	1371	1311	1254	1200	1147	1098	1050
89	2027	1931	1841	1757	1677	1602	1531	1463	1400	1339	1281	1226	1173	1123	1075
90	2062	1966	1875	1789	1708	1633	1561	1492	1428	1367	1308	1252	1199	1148	1100

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Table of Gay-Lussac for Procuring a Weaker Alcohol of a certain Strength from a Stronger.—Continued.

1000 vol. of alcohol of per cent. by vol.	Desired Strength of the Spirit. Percent. by Volume.														
	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
31															
32															
33															
34															
35															
36															
37															
38															
39															
40															
41															
42															
43															
44															
45															
46	23														
47	46	22													
48	68	45	22												
49	91	67	44	21											
50	114	89	66	43	21										
51	137	112	87	64	42	21									
52	160	134	110	86	63	41	20								
53	183	157	132	107	84	62	41	20							
54	206	179	153	129	105	83	61	40	19						
55	229	202	176	151	127	103	81	60	39	19					
56	252	224	198	172	148	124	102	80	59	38	19				
57	275	247	220	194	169	145	122	100	78	58	38	19			
58	298	269	242	216	190	166	142	120	99	77	57	37	18		
59	321	292	264	237	212	187	163	140	118	96	76	56	37	18	
60	345	315	286	259	233	208	183	160	137	116	95	74	55	36	18
61	368	338	309	281	254	229	204	180	157	135	114	93	73	54	35
62	391	360	331	303	276	250	225	200	177	155	133	112	92	72	53
63	414	383	353	325	297	271	245	221	197	174	152	131	110	90	71
64	438	406	376	346	318	292	266	241	217	194	171	150	128	109	89
65	461	429	398	368	340	313	286	261	237	213	190	168	147	127	107
66	484	451	420	390	361	334	307	281	256	233	209	187	166	145	125
67	508	474	443	412	383	355	328	301	276	252	229	206	184	163	143
68	531	497	465	434	404	376	348	322	296	272	248	225	203	181	160
69	554	520	487	456	426	397	369	342	316	291	267	244	221	200	178
70	578	543	510	478	447	418	390	362	336	311	286	263	240	218	196
71	601	566	532	500	469	439	411	383	356	331	306	282	259	236	214
72	625	589	555	522	491	460	431	403	376	350	325	301	277	255	232
73	648	612	578	544	512	482	452	424	396	370	344	320	296	273	251
74	672	635	600	567	534	503	473	444	416	390	364	339	315	291	269
75	695	658	623	589	556	524	494	465	437	409	383	358	333	310	287
76	719	681	645	611	578	546	515	485	457	429	403	377	352	328	305
77	743	705	668	633	599	567	536	506	477	449	422	396	371	347	323
78	766	728	691	655	621	588	557	527	497	469	442	415	390	365	341
79	790	751	713	678	643	610	578	547	517	489	461	434	409	384	360
80	813	774	736	700	665	631	599	568	538	509	481	454	428	402	378
81	837	797	759	722	687	653	620	588	558	529	500	473	447	421	396
82	861	821	782	745	709	674	641	609	578	549	520	492	465	440	415
83	885	844	805	767	731	696	662	630	599	569	540	512	485	458	433
84	909	867	828	789	753	717	683	651	619	589	559	531	504	477	451
85	933	891	851	812	775	739	705	671	640	609	579	550	523	496	470
86	957	914	874	834	797	761	726	692	660	629	599	570	542	515	488
87	981	938	897	857	819	782	747	713	681	649	619	589	561	534	507
88	1005	961	920	880	841	804	769	734	701	669	639	609	580	553	526
89	1029	985	943	902	863	826	790	755	722	690	659	629	600	572	544
90	1053	1009	966	925	886	848	812	777	743	710	679	648	619	591	563

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Table of Gay-Lussac for Procuring a Weaker Alcohol of a certain Strength from a Stronger.—Continued.

1000 vol. of alcohol of per cent. by vol.	Desired Strength of the Spirit.														
	Percent. by Volume.														
	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74
61	17														
62	35	17													
63	52	34	17												
64	70	52	34	17											
65	88	69	51	33	16										
66	105	86	68	50	33	16									
67	123	104	85	67	49	32	16								
68	140	121	102	84	66	49	32	16							
69	158	138	119	101	82	65	48	32	16						
70	176	156	136	117	99	81	64	47	31	15					
71	193	173	153	134	116	98	80	63	47	31	15				
72	211	191	171	151	132	114	97	79	63	46	30	15			
73	229	208	188	168	149	131	113	95	78	62	46	30	15		
74	247	226	205	185	166	147	129	111	94	77	61	45	30	15	
75	265	243	222	202	183	164	145	127	110	93	76	60	45	29	14
76	283	261	240	219	199	180	162	143	126	109	92	75	60	44	29
77	300	278	257	236	216	197	178	159	142	124	107	91	75	59	44
78	318	296	274	253	233	213	194	176	157	140	123	106	90	74	58
79	336	314	292	271	250	230	211	192	173	155	138	121	105	88	73
80	354	331	309	288	267	247	227	208	189	171	153	136	120	103	87
81	372	349	327	305	284	263	243	224	205	187	169	152	135	118	102
82	390	367	344	322	301	280	260	240	221	203	184	167	150	133	117
83	409	385	362	339	318	297	276	256	237	218	200	182	165	148	131
84	427	403	379	357	335	313	293	273	253	234	216	198	180	163	146
85	445	421	397	374	352	330	309	289	269	250	231	213	195	178	161
86	463	438	415	391	369	347	326	305	285	266	247	229	211	193	176
87	481	456	432	409	386	364	343	322	302	282	263	244	226	208	191
88	500	474	450	426	403	381	359	338	318	298	279	260	241	223	206
89	518	493	468	444	421	398	376	355	334	314	295	275	257	239	221
90	537	511	486	462	438	415	393	372	351	331	311	291	273	254	236

1000 vol. of alcohol of per cent. by vol.	Desired Strength of the Spirit.														
	Percent. by Volume.														
	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89
76	14														
77	29	14													
78	43	28	14												
79	57	43	28	14											
80	72	57	42	28	14										
81	86	71	56	42	27	14									
82	101	85	70	56	41	27	13								
83	116	100	85	70	55	41	27	13							
84	130	114	99	84	69	55	40	27	13						
85	145	129	113	98	83	68	54	40	26	13					
86	159	143	127	112	97	82	68	54	40	26	13				
87	174	158	142	126	111	96	81	67	53	39	26	13			
88	189	172	156	140	125	110	95	81	66	53	39	26	13		
89	204	187	171	155	139	124	109	94	80	66	52	39	26	13	
90	219	202	185	169	153	138	123	108	94	79	66	52	39	26	13

The problem of procuring a weaker alcohol from a stronger, depends on a knowledge of the contraction of alcohol by its mixture with water. The foregoing table of Gay-Lussac serves for this purpose. The upper horizontal column indicates the percents. by vol. of the weaker spirit, which we desire to procure. The vertical columns under them indicate the number of vols. of water which are to be added to 1000 vols. of alcohol of the strength indicated in the left-hand vertical column in

order to produce it. Thus, if we wish to procure spirit of 33 per cent. from alcohol of 85 per cent. we take the number 33 in the upper horizontal column, and find, in the vertical column below it, the number 1628 on a horizontal line with 85, in the left-hand vertical column. 1000 vols. of alcohol of 85 per cent. therefore, require 1628 vols. of water to produce spirit of 33 per cent.

The following more accurate but less full table serves for the same purpose. The upper

horizontal column contains the per cent. of the stronger alcohol, and the vertical columns below the vols. of water which are to be added to 100 vols. of it, in order to produce spirit of the strength indicated in the left-hand column.

Desired strength in per cent.	100 vols. of Alcohol of Per Cent. by Vol.								
	90	85	80	75	70	65	60	55	50
85	6.56								
80	13.79	6.83							
75	21.89	14.48	7.20						
70	31.05	23.14	15.35	7.64					
65	41.53	33.03	24.66	16.37	8.15				
60	53.65	44.48	35.44	26.47	17.58	8.76			
55	67.87	57.90	48.07	38.32	28.63	19.02	9.47		
50	84.71	73.90	63.04	52.43	41.73	31.25	20.47	10.35	
45	105.34	93.30	81.38	69.54	57.78	46.09	34.46	22.90	11.41
40	130.80	117.34	104.01	90.76	77.58	64.48	51.43	38.46	25.55
35	163.28	148.01	132.88	117.82	102.84	87.93	73.08	58.31	43.59
30	206.22	188.57	171.05	153.61	136.04	118.94	101.71	84.54	67.45
25	266.12	245.15	224.30	203.53	182.83	162.21	141.65	121.16	100.73
20	355.80	329.84	304.01	278.26	252.58	226.98	201.43	175.96	150.55
15	505.27	471.00	436.85	402.81	368.83	334.91	301.07	267.29	233.64
10	804.54	753.65	702.89	652.21	601.60	551.06	500.59	450.19	399.85

ALE. *Tech.* A variety of beer made from pale malted barley. See **BEER**.

ALEMBIC. *Chem.* The term alembicus was formerly used for the capital of a still; subsequently, alambic or alembic was applied to a glass still consisting of a flask with a capital from which passes a tube. It is now very rarely employed.

ALEMBROTH, SALT OF. *Chem.* A double salt of chloride of mercury with chloride of ammonium ($\text{NH}_4\text{Cl} + \text{HgCl} + \text{HO}$), long since known, has latterly been recognised as one of a class of haloid salts, in which, according to Bonsdorff, the chloride of mercury acts the part of an acid to the chlorides of more electropositive metals. See **Salts of MERCURY**.

ALGAROTH, POWDER OF. *Chem.* Oxichloride of antimony; according to Berzelius, $\text{SbCl}_3 + 3\text{SbO}_3 + 3\text{HO}$; according to Malaguti and Johnstone, $2\text{SbCl}_3 + 9\text{SbO}_3$. See **Salts of ANTIMONY**.

ALGÆ. *Bot.* See **SEA-WEED**.

ALIMENTARY PRINCIPLES. The following extracts from Pereira's *Materia Medica* convey a sufficiently extended view of the subject. For details respecting the several substances, see the articles on them in the present work.

Dr. Prout has divided the alimentary principles into three great classes or groups—the *saccharine*, the *oleaginous*, and the *albuminous*, to which he has latterly added a fourth, the *aqueous*. He was led to this division by observing that milk, the only article actually furnished and intended by nature as food, always contains a saccharine principle, a butyraceous or oily principle, and a caseous, or, more correctly speaking, an albuminous principle.

CLASS 1. Saccharine Principles. The principles contained in this class are Sugar, Gum, Vegetable Jelly, Starch, and Lignin. These agree in being of vegetable origin, and in consisting of carbon, hydrogen, and oxygen. With the exception of pectin or vegetable jelly, they contain oxygen and hydrogen in the ratio to form water; and might, therefore, be termed *hydrates of carbon*.

Those varieties of each principle which contain the smallest quantity of water, Dr. Prout terms *strong* or *high*; while those containing the largest proportion of water, he denominates *weak* or *low*. Thus, sugar-candy is a high or strong sugar,—sugar of starch, a weak or low one.

1. *Saccharine Substances.* Under this head are placed several sweet organic principles, capable, for the most part, of undergoing vinous fermentation when mixed with yeast and a due proportion of water.

a. **SUGARS SUSCEPTIBLE OF VINOUS FERMENTATION.**

1. *Crystallisable.* This division includes common sugars (viz. cane, maple, and beet-root sugars), granular sugars (viz. grape, honey, starch, and diabetic sugars), and sugar of milk.

2. *Uncrystallisable.* Called liquid or mucous sugars, as treacle.

b. **SUGARS UNSUSCEPTIBLE OF VINOUS FERMENTATION.**

1. *Crystallisable.* Mannite.

2. *Uncrystallisable.* Glycyrrhizin, Glycerin, and Sarcocollin.

Sugar is a highly nutritious substance, and by the healthy stomach is readily digested. It appears to be especially adapted for the food of young plants; hence we find it generated in many seeds (as peas, barley, &c.) during germination. It is nutritive to animals. Thus it is an important constituent of milk; a liquid intended for the nourishment of mammals during the first period of their existence. It is employed by man on account of its agreeable taste, rather than as a direct source of nourishment; yet, of its nutritive qualities few entertain any doubt. The injurious effects which have been ascribed to it are more imaginary than real. Some individuals have consumed large quantities of it, for a long series of years, without suffering any ill consequences.

2. *Mucilaginous Substances.* The gummy principles, called Arabin, Tragacanthin or Adraganthin, Cerasin or Prunin, Cydonin, and Bas

sorin, belong to this group. They possess nutritive properties, but are somewhat difficult of digestion.

Hasselquist (*Voyages and Travels in the Levant*, p. 298, Lond. 1766) tells us, that a caravan of more than a thousand persons, travelling from Abyssinia to Cairo, and whose provisions were exhausted, supported themselves for two months on the gum they were carrying as merchandise. The Moors and the Negroes near the Niger employ it as a common kind of food. The Hottentots also are well aware of its nutritive properties.

3. *Vegetable Jelly*. To this head are referred Pectin or Groussulin, and Carrageenin. These are nutritive and digestible.

4. *Amylaceous, farinaceous, or starchy substances*. Under this division are included Wheat-starch, Sago, Tapioca, Arrow-root, Potato-starch, Salop, &c. Amylaceous matter is found in various parts of plants.

When cooked, amylaceous matter is a nutritious and easily digestible substance. Directly or indirectly, observes Dr. Prout, "it forms a constituent of the food of most of the higher animals, as well as of man. It differs, therefore, from sugar, in being a *necessary* article of food, without which animals could not exist; while sugar is not. Hence a much larger quantity of amylaceous matter than of sugar can be taken; and what is a still more decisive fact, the use of this larger quantity of amylaceous matter may be persisted in for an unlimited period, which, it appears, is not the case with a large proportion of sugar."

5. *Lignin or Woody Fibre*. It "forms the appropriate food of numerous insects and of some of the lower animals, but of few of the higher classes of animals. The reason of this is probably to be sought for in their not being furnished with organs proper for comminuting and reducing it; for when lignin is comminuted and reduced by artificial processes, it is said to form a substance analogous to the amylaceous principle, and to be highly nutritious." (Prout.)

The Laplanders, according to Linnæus, eat bark-bread (*barkbröd*) during a great part of the winter, and sometimes even during the whole year. It is prepared from the inner bark of the *Pinus sylvestris*.

CLASS 2. Oleaginous Alimentary Principles. This class comprehends the substances denominated Fats, Fixed Oils, and Butter.

Oleaginous aliments are highly nutritious, but exceedingly difficult and slow of digestion.

Sir John Ross considers (and his opinion is probably correct) that the natives of cold countries seem to require a more fatty diet than the inhabitants of tropical regions, in order to promote the production of animal heat.

CLASS 3. Nitrogenous Alimentary Principles. The most important alimentary principles, containing nitrogen, are Fibrines, Albumen, Caseum, Gelatine, and Gluten. The animal extract, called Osmazome, is also a nitrogenous principle. With one exception (Gluten), these principles are obtained from the animal kingdom, and they have, in consequence, been frequently denominated *animal* aliments.

Fibrine is eminently nutritious, and easy of digestion.

Albumen is highly nutritious, and when either raw or lightly boiled, is easy of digestion; but when boiled hard, or especially when fried, its capability of being digested is considerably impaired.

Caseum is nutritious, and moderately easy of digestion.

Gelatine. *Animal Jelly* is an exceedingly nutritive principle, though probably somewhat less so than fibrine and albumen.

Gelatine from Bones is employed in Paris for the preparation of a nutritious soup for hospitals and other pauper habitations.

Confectioner's Jelly is made from isinglass, calves' feet, and patent gelatine.

Soups and Broths owe their nutritive properties principally to gelatine.

Young meats yield more gelatine than old ones.

Osmazome. To this principle broths and soups owe their flavour, smell, and part of their nutritive qualities.

Gluten is believed to be highly nutritious, and to confer on wheat flour its well-known superior alimentary qualities. "Its viscosity or tenacity confers upon that species of flour its peculiar excellence for the manufacture of *macaroni*, *vermicelli*, and similar pastes, which are made by a kind of wire-drawing, and for which the wheat of the south of Europe (more abundant in gluten than our own) is particularly adapted." (Brande.)

ALIXIA-CAMPHOR. *Chem.* Nees v. Esenbeck, Jr., describes it as sometimes occurring on the inner side of the bark of *Alixia aromatica*. White, capillary crystals, of a feeble aromatic and agreeable odor. Sublime at 140° to 160°, undecomposed without fusion, at a high temperature fuse and change into a brown substance. Soluble in warm, not in cold water; the solution does not affect litmus, nor neutralize alkalies, and deposits by evap. at 95° to 105°, the crystals unaltered; the liquor distilled acts similarly. Alcohol (of 80 per cent.), ether, oil of turpentine, acetic acid, caustic and carbonated potassa and ammonia dissolve it readily; nitric acid (1·2 sp. gr.) colors it yellow without dissolving it. (*Handwört. d. Chem.* i. 191.)

ALIZARIN. *Chem.* A crystallised red coloring substance, obtained by sublimation from madder, by Robiquet and Colin.

Prep. Moisten 1 pt. ground madder with $\frac{1}{2}$ to 1 pt. sulphuric acid, adding gradually to prevent the heat rising above 160°. After 2 or 3 days nearly every thing in the madder is charred except alizarin; wash out the acid from the black mass, digest with a little cold alcohol, dissolve the A. with boiling alcohol, distil off and collect the A. on a filter; or heat the washed and dried black mass gently, when silky, red tufts of crystals sublime. (*Rob. and Col.*) Extract madder with ether, distil and sublime the residue.

Prop. Alizarin forms transparent red or yellowish-red, 4-sided, silky needles or laminæ, slightly soluble in water with a red color, readily in 210 pts. alcohol or 160 pts. ether, at 54° with a golden yellow color; the solutions

have an acid reaction (*Zenneck*); alkalis dissolve it with a violet color, which when diluted is red. Cotton based with acetate of iron or alumina, and dipped into its solution in a little alcohol and much water, assumes the tints and fastness of the best madder-dyed goods.

Madder has been examined by several others, and the experiments of Runge especially show that alizarin is not a simple color, and that madder contains several others. See **MADDER**.

ALKAHEST. The alchemists applied this term to a supposed universal solvent.

ALKALI. *Chem.* Derived from the article (al) and (kali) the name of a plant in the Arabic. It was formerly applied to the ashes of plants, latterly to designate the vegetable, mineral, and volatile alkalis potassa, soda, and ammonia. See **ALKALIES**.

ALKALIES. *Chem. Tech. Syn. Ger.* Alkalien. *Fr.* Alcalis. The general characteristics of alkalis are, their ready solubility in water, power of neutralizing the strongest acids, which is also a test of their purity and strength, their capability of changing many vegetable blue colors to green, and some yellows to brown, or of restoring the colors of those which have been changed by acids: among these the yellow of turmeric and reddened litmus are exceedingly delicate tests of the presence of an alkali.

The alkalis are potassa, soda, and lithia, formed by the union of oxygen with their metallic bases. Their affinity for oxygen is so powerful as to enable them to decompose the coldest water and even ice instantaneously, with the disengagement of hydrogen.

To these might be added baryta, strontia, lime, and magnesia, which have certain properties in common with the alkalis proper, and on this account are sometimes classed with them. See **ALKALINE EARTHS**. The chief mode of distinguishing between the alkalis and alkaline earths is, in the solubility of the carbonated alkalis and their power of changing blue and yellow colors, which do not belong to the carbonates of the alkaline earths.

Ammonia must also be considered as an alkali, having similar properties, although differing from them in its organic constitution, for it is of great importance both in elementary chemistry and to the arts.

Sources. Potassa is generally obtained as a carbonate from the ashes of plants growing at a distance from the sea, and extensively from the vast forests common to new countries. It exists abundantly in the mineral kingdom, particularly in felspar and clays.

Soda exists in great quantities as chloride of sodium (common salt) in sea-water, and in extensive natural formations. It is procured from salt and the ashes of marine plants.

Lithia occurs in a few rare minerals. Ammonia occurs massive in the state of muriate, in the vicinity and craters of volcanoes. But its most common source is the decomposition of vegetable and animal matter.

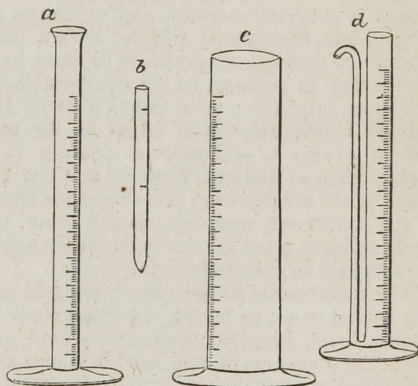
Uses. The alkalis potassa and soda are extensively employed in chemistry and the chemical arts. Their use depends on their

strong basic properties, and on their faculty of forming fusible compounds with silicic acid. Being strong bases, they are frequently employed by the chemist to effect the decompositions of salts by abstracting their acid, and to form soluble combinations; they are farther used for the same reasons to combine with the acids in fats, with which they form soluble soaps. From their forming fusible compounds with silica, they are used extensively in fluxing, as in the manufacture of glass, &c. Ammonia is employed by the chemist from its strong basic properties, its volatility, and the solubility of its salts. In the arts it has a limited application. See **POTASSA**, **SODA**, **LITHIA**, **AMMONIA**.

ALKALIMETER. *Tech.* An apparatus for determining the quantity of pure or *real potassa* or *soda*, or pure carbonate, in a commercial carbonate. Its use depends on the quantity of acid required to neutralize a given quantity of the carbonate.

ALKALIMETRY. *Tech.* The process of ascertaining the quantity of pure carbonated alkali in a commercial carbonate, by means of the alkalimeter. The simplest method is to determine how many measures of a dilute sulphuric acid are required to neutralize 100 grains of the carbonate. Suppose we wish to test the (carbonate of) soda of commerce.

1. Prepare the alkalimeter, a glass tube 14 inches high and $\frac{5}{8}$ inch wide, fig. a, with a foot



or stand, capable of holding a little more than 1000 grains of water. Graduate it into 100 parts, each of which contains 10 grs. water. It is better to divide it by mercury, 135.68 grs. of which = the bulk of 10 grs. water. Take a glass tube, *b* in the figure, of proper size, pour into it 678.40 grs. mercury = 50 grs. water by volume, closing the lower orifice by the finger, and mark the height of the mercury by a scratch on the tube. Twice that volume of mercury may also be marked. Pour the 678.4 grains of mercury into the alkalimeter, and mark its height by a scratch, which will be 5 of the 10-grain measures of water. Another measure is added to the preceding, and its height marked, and thus 20 such measures will mark the 50 grains + 20 = 1000 grains water. Make the subdivisions of each of the 20 spaces between the marks by the eye, and mark them also on the alkalimeter. Number the divisions

ALKALINE EARTHS.

from the top 0, 5, 10, &c. to the bottom, which = 100. The French alkalimeter, *d*, is more convenient, but the small tube is too liable to fracture.

2. The sulphuric acid is of such a strength that 1 measure of it in the alkalimeter (10 grs. water measure) will exactly neutralize 1 gr. pure soda. Weigh out 170.6 grs. pure carbonate of soda, which contain 100 grs. soda, dissolve it in 4 or 5 ounces of hot water. Mix 1 pt. by weight of oil of vitriol with 5 pts. of water, and fill the alkalimeter with it up to 0. Pour the acid into the soda-solution until it ceases to act alkaline on reddened litmus paper, and is distinctly acid, and note the measures of acid used, suppose it to be 90 measures. Then add 10 more measures of water, so that the real acid formerly in 90 will now be in 100 measures, and will neutralize 100 grs. soda, or each measure 1 gr. soda. This acid has a density of 1.0995 to 1.0998, or practically 1.1. Concentrated sulphuric acid happens to have this density when mixed with 11 times its weight of water. The mixture is conveniently made in a graduated vessel, *c*.

3. To test the commercial soda, dissolve 100 grains of it in 2 or 3 ounces of hot water; pour the acid into the solution until alkaline reaction ceases, and observe the number of measures used. Every measure of acid is equivalent to 1 gr. or 1 per cent. of pure soda. If the crude soda contain insoluble matter, its solution should be filtered previous to testing. Where it contains sulphite and sulphuret of sodium, mix the filtered solution with a little chlorate of potassa, evaporate to dryness, heat the residue to redness, which converts those salts into sulphates; then test as above. Or, find the whole amount of alkali by the test, add an excess of chloride of calcium to a fresh portion of 100 grs., filter off and test the liquid by the alkalimeter; this shows the alkali in the sulphuret, and, subtracted from the whole amount, gives the real soda, which exists as carbonate in the crude soda.

When carbonate of potassa (pearlash, potash, ashes) is to be tested, the equivalent of potassa being higher, requires less acid, and where the measures of acid used in a soda and potash test are equal, it indicates more potassa in the ratio of their equivalents, 47.26 potassa to 31.31 soda, or about 6 to 4. Hence, to test potash, pursue the course pointed out for soda, then multiply the number of measures used by 6 and divide by 4; the quotient is the per cent. potassa.

ALKALINE EARTHS. *Chem. Syn. Ger.* Alkalische Erden. *Fr.* Terres alcalines, or Alcalis. These are the results of the union of oxygen and the metallic bases barium, strontium, calcium, and magnesium, all of which, with the

ALKALOIDS.

exception of the last, decompose water rapidly at common temperatures. The term alkaline earths is derived from the properties possessed by them in common with the alkalis proper, while in other respects they resemble the earths. Baryta, strontia, and lime are strongly caustic, magnesia less so. The two former are rather soluble in water, lime less so, and magnesia requires a very large quantity of water for solution. See BARYTA, STRONTIA, MAGNESIA, LIME.

ALKALOIDS. *Chem. Syn.* Similar in *Ger.* and *Fr.* These substances are peculiar to vegetables and exist as salts in the juices of the plants. Most of the organic bases are ready formed in plants and are termed vegetable bases, others are formed during decomposition. The name alkaloids or vegetable alkalis is applied to those which in solution restore the blue of reddened litmus. Sertuerner, in 1804, discovered the first base, since which time many additions have been made.

Prep. The manner of their extraction from plants varies of course with their several properties. They may for the most part be obtained by boiling in water acidulated with sulphuric or muriatic acids, and neutralizing the filtered solution by means of ammonia, lime, or magnesia. We thus obtain the organic alkali as a precipitate to be subsequently purified and crystallised from their alcoholic solutions.

Properties. Most of them are solid, inodorous, crystallisable; some are pulverulent, liquid or volatile; and some even highly odorous; all are combustible, having an alkaline action upon vegetable coloring matters, and forming salts with acids. Such as are known are but little soluble in water; they may, however, be easily dissolved in boiling alcohol.

The constituents of all the alkaloids are carbon, hydrogen, and nitrogen: oxygen is common to most, yet there are many destitute of this element; such are very strong bases. It has been found that those containing oxygen neutralize more acid the less their content of oxygen, thus differing very materially from the inorganic alkalis.

Most of the alkaloids contain but one equivalent of nitrogen, some, however, contain 2 or more equivalents. This nitrogen, it will be observed, does not exist in the alkalis in the form of ammonia, though generally in such a state as to form ammonia as a product of decomposition. The vegetable bases have been found to possess properties highly medicinal or poisonous, proportionate to the quantities administered. The principal substances of the class of alkaloids, together with the plants from which they are obtained, their formula, and the names of their discoverers, are the following—

Name.	Whence obtained.	Formula.	Authority.
1. Volatile Bases.			
Aniline.....	Indigo	$C_{12}H_6N$	Unverdorben & Fritzsche
Nicotine.....	Tobacco plant	$C_{10}H_8N$	Reimann & Posselt
Conicine.....	Conium maculatum	$(?)C_{12}H_{14}NO$	Gieseke & Geiger

Name.	Whence obtained.	Formula.	Authority.
2. Bases from Oil of Mustard.			
Thiosinamine.....	Oil of mustard	$C_8H_8N_2S_2$	Varrentrapp & Will
Sinamine.....	Ditto	$(?)C_8H_6N_2$	Do.
Sinapoline.....	Ditto	$C_{14}H_{12}N_2O_2$	Simon
3. Bases from Cinchona Bark.			
Aricine.....	Aricas bark	$C_{20}H_{12}NO_3$	Pelletier
Quinine.....	Cinchonia regia vera	$C_{20}H_{12}NO_2$	Pelletier & Caventou
Cinchonine.....	Cinchonia oblongifolia	$C_{20}H_{12}NO$	Liebig
Chinoidine (?).....	Mother liquors of Quinine	Not determined	
4. Bases of the Papaveraceæ.			
Morphia.....	Opium	$C_{35}H_{20}NO_6$	Sertuerner
Codeine.....	Opium	$C_{35}H_{20}NO_5$	Robiquet
Thebaine.....	Opium	$C_{25}H_{14}NO_3$	Thiboumery
Pseudomorphine.....	Opium	$(?)C_{27}H_{18}NO_4$	Pelletier
Narceine.....	Mother liquor of Morphia	$(?)C_{32}H_{24}NO_{16}$	Pelletier & Couerbe
Narcotine.....	Opium	$C_{40}H_{20}NO_{12}$	Derosne
Chelidonine.....	Chelidonium majus	$C_{40}H_{20}N_3O_6$	Godefroy
Glaucine.....	} Glaucium luteum	Not determined	Probst
Glaucopirine.....			
5. Bases in Solanaceæ, Strychnaceæ, &c.			
Hyoscyamine.....	Hyoscyamus niger	Not determined	Geiger & Hesse
Daturine.....	Datura Stramonium	Ditto	Do.
Stramonine.....	Daturine liquor	Ditto	Trommsdorff
Atropine.....	Atropa Belladonna	$(?)C_{34}H_{23}NO_6$	Mein, Geiger, & Hesse
Solanine.....	Solanum nigrum	$C_{84}H_{68}NO_{28}$	Blanchet & Otto
Veratrine.....	Veratrum Sabadilla	$C_{62}H_{45}N_2O_{12}$	Couerbe
Jervine.....	Ditto	$C_{60}H_{45}N_2O_6$	Simon
Sabadilline.....	Ditto	$(?)C_{40}H_{25}N_2O_{10}$	Couerbe
Strychnine.....	Nux vomica	$C_{44}H_{23}N_2O_8$	Pelletier & Caventou
Brucine.....	Brucia antidysenterica	$C_{44}H_{25}N_2O_7$	Regnault
Delphine.....	Delphinium staphysagria	$(?)C_{27}H_{19}NO_2$	Couerbe
Staphysine.....	Ditto	$(?)C_{32}H_{23}NO_2$	Do.
Aconitine.....	Aconitum Napellus	Not determined	Geiger & Hesse
Picrotoxine.....	Cocculus Indicus	Ditto	Boullay
Menispermine.....	Ditto	$(?)C_{18}H_{12}NO_2$	Pelletier & Couerbe
Paramenispermine...	Ditto	Ditto	Do.
Emetine.....	Cephælis ipecacuanha	$C_{37}H_{27}NO_{10}$	Pelletier
Harmaline.....	Peganum Harmala	$C_{24}H_{13}N_2O$	Varrentrapp & Will
Piperine.....	Pepper	$C_{34}H_{19}NO_6$	Regnault
Berberine.....	Berberis vulgaris	$C_{38}H_{18}NO_{12}$	Euchner
Corydaline.....	Corydalis bulbosa	$C_{34}H_{22}NO_{10}$	F. Dabereiner
Caffeine.....	Coffee and tea bohea	$C_8H_5N_2O_2$	Pfaff
Theobromine.....	Theobroma cacao	$C_9H_5N_3O_2$	Woskresensky

ALKALOIMETER. *Phar.* An instrument for ascertaining the quantity of real vegetable alkali in the commercial article. O. Henry endeavored to do this in a small alkalimeter, using a strong solution of tannin (prepared by displacement), instead of dilute acid. To a strong solution of the alkaloidal sulphate, the tannic acid solution is added as long as a precipitate occurs. The precipitate is a bitannate (Henry) of the alkaloid, not wholly insoluble. To be sensible, the liquid should contain at least $\frac{1}{2000}$ of quinin, cinchonin, narcotin, strychnin, or brucin, and $\frac{1}{500}$ o. morphia or codein. Henry used a test fluid, containing 5 per cent. tannin, which should always be fresh, as it spoils by keeping. He determined by it quinin and cinchonin, the former requiring 2.5, the latter 2.71 pts. tannin. This mode of testing the alkaloids is of doubtful utility.

ALKANA. *Tech.* The true or oriental alkanet is the root and leaves of the *Lawsonia*

inermis, or Henna plant, which are employed in the East chiefly to dye the nails, teeth, garments, &c., of a pink color. The leaves, with lime and water, are also used for dyeing the tails and manes of horses, in Persia, &c.

ALKANET. *Tech.* The root of the *Anchusa tinctoria*, a species of bugloss, containing a red coloring matter, and hence employed in dyeing and coloring. The bark of the root, analyzed by John, gave 5.5 coloring matter, 6.5 gum, 1.0 soluble extractive matter, 65.0 extractive deposit soluble in potassa (loss 4.25). The root-wood consisted mainly of woody matter. The coloring matter is the only important principle.

Alkanet, Red. *Syn.* Anchusine, anchusic acid. *Ger.* Alkannaroth. Formula, according to Pelletier, $C_{17}H_{10}O_4$.

	Experiment.	Calculation.	Equiv.
Carbon....	71.178	71.23	17
Hydrogen....	6.826	6.84	10
Oxygen....	21.996	21.91	4

ALLANTOIC FLUID.

Prep. Extract the root by ether (*John*), by boiling absolute alcohol (*Pelletier*), evaporate to dryness; and when alcohol is used, extract the residue by ether, and again evaporate; or, according to *Berzelius*, extract other matters by water, then the color by water containing a little carbonate of potassa or soda, and precipitate the color by an acid.

Prop. A dark-red body of a resinous lustre, belonging rather to the electro-negative or acid resins; insoluble in water, readily in ether, alcohol, and in the fixed and volatile oils, with a red color; in sulphuric, with amethyst color, precipitated again by water; cold nitric attacks it slightly. Excess of alkali dissolves it with a blue color; the compounds, with the alkaline earths, are blue, and less soluble. When dissolved in alcohol, an aqueous solution of protochloride of tin precipitates it carmine-red; basic acetate of lead, a beautiful blue; iron salts, a dark violet, and chloride of mercury, a flesh-red. Its compounds with the alkalies and alkaline earths are soluble in ether and alcohol, and hence *Pelletier* classes it with the fat acids; but *Berzelius* does not admit this.

Uses. Employed to a limited extent in dyeing, for a beautiful purple or violet. For this purpose common alcohol is poured over the root until it covers it, and after 12 hours decanted on a 2d portion of root, while fresh alcohol is poured on the 1st; it should thus pass through several vessels until the alcohol is not quite saturated. It is then mingled with pure water, and the goods bated with acetate of alumina (red liquor) passed into it, and dyed by a slowly increasing heat, to boiling. It constitutes an extremely fast color, not being altered by lime-water, ammonia, acetic, or citric acids, tin salts, or chloride of lime. Potash and soda produce blue spots on the goods, which vinegar restores even after 24 hours.

	1.	2.	3.	4.
Silica.....	35.4	33.021	34.0	30.17
Alumina	4.1	15.226	9.0	11.31
Protoxide of cerium.....	31.5	21.600	19.8	28.19
Protoxide of iron.....	22.8	15.101	(Fe ₂ O ₃) = 32.0	20.72
Protoxide of manganese.....	—	0.404	—	—
Lime.....	9.2	11.080	—	9.12
Water.....	—	3.000	—	(CuO) = 0.87
Volatile matter	4.0	—	—	—
	107.0	99.432	94.8	100.38

Berzelius constructs from *Stromeyer's* analysis the formula $(3 \text{ FeO}, \text{SiO}_3 + 3 \text{ CeO}, \text{SiO}_3) + (3 \text{ CaO}, \text{SiO}_3 + 2 \text{ Al}_2\text{O}_3, \text{SiO}_3)$. The formula of cerine is less certain, and indeed the discoveries by *Mosander* of lanthanum and didymium, require that these minerals should be tested for those metals.

ALLANTOIC FLUID. *Anat.* The space between the allantoids and amnion of most mammalia contains the urine of the fœtus, called the allantoid fluid. The A. fluid of the cow contains allantoin, albumen, lactate of alkali, ammonia, phosphates, and common salt. Alcohol extracts allantoin and a yellowish brown substance, the former is obtained by evaporation and crystallisation. It has not

ALLANTOINE.

Soap-water brightens it. Light alone affects it and that to a limited extent.

It is farther used for coloring tinctures, spurious port wine, for giving a fine rose-color to lip-salve, pomatum, and other ointments; and its alcoholic solution communicates a pleasing stain to marble.

ALLAGITE. *Min.* See MANGANESE SPAR.

ALLANITE (Allanite and Cerine). *Phys. Char.* Cryst. Doubly oblique rhombic system, M predominating. Cleav. imperfect parallel to M and T. Occurs also acicular, and finely granular.—H = 6. Spec. grav. 4, when pure. Color, brownish or greenish black; lustre, sub-metallic, shining; sub-translucent to opaque; brittle; fracture uneven, passing into small conchoidal.

Chem. Char. Greenland allanite fuses easily before the blowpipe to a brownish or blackish magnetic glass. (*V. Kobell*.) Cerine from *Bastnäsgrube* yields water in a bulb; fuses before the blowpipe to a black glassy bead, dissolves easily in borax, the glass is black, opaque, becomes in the exterior flame blood-red when hot, more or less yellow on cooling; in the inner flame, green; mic. salt dissolves it, leaving a skeleton of silica; the bead shows an iron color when hot, colorless and opalescent when cold; soda dissolves it to a black glass. (*Berzelius*.)

The Greenland A. gelatinizes with nitric and muriatic acids; the Swedish C. is imperfectly attacked by acids.

Analysis. 1. By *Thomson*, from Alluk in Greenland (*Trans. R. Soc. Edinb.* vi. 371); 2, by *Stromeyer* from *Iglorsoit*, Greenl. (*Pogg. An.* xxxii. 289); 3, by *Wollaston* from Mysore (*Liebig and Pogg. Wörterb.* 1.265); and, 4, of cerine by *Hisinger* from *Bastnäsgrube* at *Riddarhyttan*, Sweden. (*Afhandl. i Fisik*, iv. 327.)

been examined for urea. (*Vauquelin and Buniva*.)

ALLANTOINE. *Chem.* Syn. Allantoic acid, Amniotic acid. Discovered by *Vauquelin* and *Buniva* in the allantoid fluid of the cow. Formed when uric acid is boiled with peroxide of lead in water. (*Wöhler and Liebig*.)

Prep. One part of uric acid is boiled in 20 parts of water, and recently prepared and well-washed peroxide of lead is added in successive portions to the boiling liquid as long as its color is observed to change. The hot liquid should be filtered, and evaporated until crystals are observed to form upon its surface. The crystals which have deposited when the solution has become quite cold are purified by

ALLANTURIC ACID.

ALLOPHANE.

recrystallisation. Or, the allantoinic fluid of the cow may be evaporated to $\frac{1}{4}$ its volume, and the crystals formed on cooling and long standing are purified by animal charcoal.

Prop. Small transparent and colorless prisms of the right rhombic system, which have a glassy lustre, are tasteless, have no action on vegetable colors, and are soluble in 160 parts of cold, but more freely in hot water. It is soluble in nitric acid, and is decomposed by it when the solution is boiled without the evolution of nitrous fumes. See ALLANTURIC ACID, below. Its composition is such that it contains the elements of anhydrous oxalate of ammonia minus 3 eq. water; this explains its decomposition by the alkalis, by which it is reduced at the boiling heat into an oxalate and ammonia. Gently heated in concentrated sulphuric acid, it is decomposed into carbonic oxide, carbonic acid, and sulphate of ammonia;

but if a strong heat be rapidly applied, the acid is blackened. It is soluble in caustic and carbonated alkalis by the aid of a gentle heat, and may be again obtained unchanged by crystallisation. A solution of allantoinic acid in hot water, to which a little ammonia has been added, produces, with the nitrate of silver, a white precipitate, which contains 43.56 per cent. of oxide of silver, and is composed as represented by the formula $C_8H_4N_4O_6 + AgO$; it consequently contains 2 eq. allantoinic acid, $C_8H_4N_4O_6$ —1 eq. water (HO)—+1 eq. oxide of silver. (*Liebig's Turner.*)

Water at a high temperature converts allantoinic acid into ammonia, carbonic and allanturic acids, no urea being formed, as it is easily converted at a little above 212° into carbonate of ammonia. These 2 decomp. were effected in closed tubes in an oil bath at 279° to 347° Fahr. (*Pelouze.*)

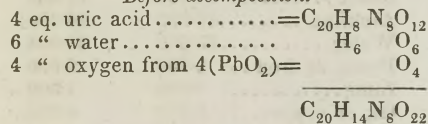
Formula of allantoinic acid, $C_4H_3N_2O_3$ or $2Cy + 3HO$.

Composition.	H=1	O=100	In 100 parts.
4 eq. carbon	24.03	300.48	30.29
3 " hydrogen	3.00	37.50	3.78
2 " nitrogen	28.38	354.07	35.69
3 " oxygen	24.03	300.00	30.24
1 " allantoinic.....	79.44	992.05	100.00

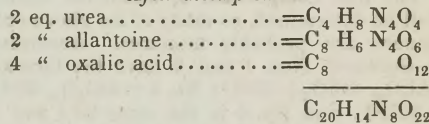
Formation. After the separation of allantoinic acid in the above method of prep. from uric acid, the residue evaporated yields urea, with some allantoinic acid, and the brown oxide of lead

has changed to oxalate of lead. The following diagram illustrates the formation of these several compounds:

Before decomposition.



After decomposition.



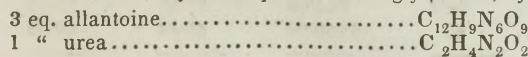
ALLANTURIC ACID. *Chem.* Pelouze (*An. de Chim. et Phys.* Sept. 1842) heated uric acid gently with nitric acid (of spec. grav. 1.2 to 1.4), when it dissolved, and on cooling, fine crystals of nitrate of urea separated. The same action takes place with hydrochloric acid, no gas in either case being generated. When the nitric solution, evap. and dried at 80° , is treated with a little water and ammonia, a white, viscid matter is precip. by alcohol, which, redissolved in water and again precip. by alcohol, to free it from nitrate of ammonia and urea, constitutes a new nitrogenous acid with a formula $C_{10}H_7N_4O_9$.

It is uric acid + 3 eq. water. It is white, slightly acid, deliquescent, nearly insoluble in alcohol. Distilled, it yields a product strongly

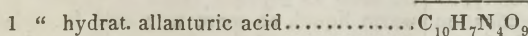
prussic, and leaves a voluminous charcoal. Acetate of lead and nitrate of silver afford voluminous white precipitates, soluble in excess of the salts and of acid.

The new acid is generated under several other circumstances. It is always formed on decomposing uric acid and allantoinic acid by peroxide of lead. Without doubt many oxidizing bodies form it from uric acid. Pelouze believes that the urea is the result of the decomp. of allantoinic acid, which is formed without urea in the first stage of the decomp. of the uric acid.

This acid is termed allanturic acid from its analogy with uric acid and its derivation from allantoinic acid; and is solely formed with urea by the action of hydrated acids on allantoinic acid. Thus, by subtracting from



$C_{10}H_7N_4O_7$ and add to the remainder H_2O_2 we have



See *Chemical Gazette*, i. 30.

ALLOCHROITE. *Min.* A variety of GARNET. **ALLOPHANE.** *Min.* Syn. Riemannite, Siliciferous hydrate of alumina. (*Phillips.*)

Phys. Char. Reniform and massive, some-

times traces of crystallisation, occasionally cleaved into apparently rectangular prisms. $H=3$. Spec. grav. 1.852—1.889. Pale blue, green, or brown; somewhat vitreous lustre;

ALLOPHANE.

translucent; streak white; fracture conchoidal, shining; very brittle.

Chem. Char. Behavior. Yields water in the bulb, and burns black in spots; the water slightly reddens litmus; swells on charcoal or in forceps without fusing, falls to powder and tinges the flame copper-green. Dissolves difficultly in borax to an almost colorless glass, which, with tin in the inner flame, becomes red from suboxide of copper. Easily dissolved in mic. salt, leaving a skeleton of silica; both in it and in soda exhibits a copper reaction. Gelatinizes with acids.

	1.
Silica	24.109
Alumina.....	38.763
Water.....	35.754
Oxide of copper.....	2.328
	100.954

	5.
Silica	30.0
Alumina	16.7
Water	29.9
Oxide of copper.....	19.2
Sesquiox. of iron....	—
Sesquiox. of mangan.	1.8
Carbonate of lime...	2.7
	100.3

The true composition of allophane cannot well be determined, as many of the above substances are probably mixtures. According to Gerhardt, Nos. 1 and 2 have the formula $3\text{Al}_2\text{O}_3, 2\text{SiO}_3 + 15\text{HO}$; No. 3 $= 3\text{Al}_2\text{O}_3, 2\text{SiO}_3 + 20\text{HO}$; and No. 4 is the same as 1 and 2, mingled with $3\text{CuO}, 2\text{SiO}_3 + 6\text{HO}$. Berthier regards A. as a compound of $\text{Al}_2\text{O}_3, \text{SiO}_3$, with 2 or 3 HO and $\text{Al}_2\text{O}_3, 3\text{HO}$. Walchner regards A. as $\text{Al}_2\text{O}_3, \text{SiO}_3 + 5\text{HO}$, and Guillemin assumes the same with hydrate of alumina.

Opalin-allophane, allied to allophane, from Freienstein, in Styria, has the following behavior and composition, according to Schrötter (*Erdm. Journ.* xi. 390).

Behaves like allophane before the B. P., but burns white; decomp. by acids. Two analyses gave

	Formula, $\text{C}_8\text{H}_4\text{N}_2\text{O}_{10}$.			
	H=1	O=100	Calculated.	Found.
8 eq. carbon	48	600.96	30.34	30.38
4 " hydrogen	4	50.00	2.47	2.57
2 " nitrogen	28.4	354.08	17.55	17.96
10 " oxygen	80	1000.00	49.64	49.09
	160.4	2005.04	100.00	100.00

It is best prepared, according to Gregory, by the following method, which is a modification of the original process of Wöhler and Liebig:—Uric acid is gradually added to nitric acid, spec. grav. 1.35, by which it is dissolved with effervescence. The action must be gentle, and, if heat be applied, it must be done cautiously.

ALLOXAN.

Analysis. Allophane 1, from Gersbach, in the Schwarzwalde, by Walchner, (*Schw. Jour.* xlix. 154); 2, from Fermi, France, by Guillemin (*An. Ch. Ph.* xlii. 260); 3 and 4, from Beauvais, France, by Berthier (*An. d. Mines*, 3me Ser. ix. 498); 5, from Gräfenthal, near Saalfeld, by Stromeyer (*Examinations*, 308); 6, from Schneeberg, by Ficinus (*Schw. Jour.* xxvi. 277); 7, from Bleiberg, in the Eifel, by Bergemann (*Ch. Exam. of Min. from Bl.* 1830, 194); 8, from Friesdorf, near Bonn, by Bunsen (*Pogg. An.* xxxi. 53).

	2.	3. Cryst.	4. Pulverulent.
	23.76	21.9	26.3
	39.68	29.2	34.2
	35.74	44.2	38.0
	0.65	Clay=4.7	1.5
	99.83	100.0	100.0

	6.	7.	8.
Silica	21.992	21.05	19.350
Alumina	32.202	30.37	32.725
Water	41.301	40.23	40.225
Oxide of copper.....	19.2 ($\text{CuO} + \text{CO}_2 = 3.058$)	—	2.575
Sesquiox. of iron....	— (Hydrate 0.270)	2.74	0.300
Sesquiox. of mangan.	— ($\text{MgO} + \text{CO}_2 = 2.06$)	—	—
Carbonate of lime...	2.7 (Lime=0.730)	2.39	2.825
	— (Gypsum 0.577)	—	— (Gypsum=0.700)
	—	—	— (Quartz=0.175)
	99.879	98.84	98.875

Silica	11.950	11.935
Alumina	46.300	46.284
Water.....	36.200	35.504
Perox. of iron ...	2.950	2.656
Lime.....	1.298	1.029
Ox. of copper....	0.250	0.250
Sulphuric acid...	0.780	0.482
	99.729	98.140

For which he establishes the formula $4\text{Al}_2\text{O}_3, \text{SiO}_3 + 18\text{HO}$, but Rammelsberg thinks it should be $(2\text{Al}_2\text{O}_3, \text{SiO}_3 + 12\text{HO}) + 2\text{Al}_2\text{O}_3, 3\text{HO}$.

ALLOXAN. *Chem. Syn.* Erythric acid, so called by its first observer, Brugnatelli, rediscovered by Wöhler and Liebig, by the action of nitric on uric acid.

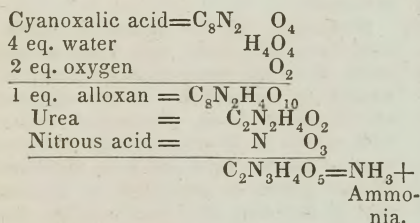
As soon as crystals begin to appear in the warm liquid, no more uric acid is added for the present, and the whole is allowed to cool, when it becomes semi-solid from the separation of the crystals of alloxan. The mass is thrown on a funnel, stopped with a little asbestos, and, when it has ceased to drop, the

acid liquor remaining in the crystals is carefully displaced by a little ice-cold water. The crystals are purified by solution in water, avoiding a strong heat, and recrystallisation. The acid liquid which has drained from the first crystals is again treated as above with uric acid, and in this way one portion of nitric acid may be made to yield 4 or 5 crops of crystals of alloxan. The mother-liquid finally left is not lost, but yields a large quantity of parabanic acid, oxalurate of ammonia, or murexide, if properly treated. (See those compounds.) By this process, Gregory obtains from 100 parts of uric acid, 65 parts of anhydrous alloxan, equal to at least 90 of the hydrated crystals.

Prop. On the cooling of a warm but not perfectly saturated solution of alloxan, it is obtained in large colorless and transparent crystals of the right prismatic system, and of a strong adamantine lustre; these crystals effloresce rapidly, losing 25 per cent. = 6 eq. water, and are converted when gently warmed, with the loss of water, into anhydrous alloxan. If a hot saturated solution be allowed to crystallise in a warm place, anhydrous alloxan is deposited directly from the solution in oblique prisms, on the extremities of which truncated rhomboidal octohedrons are seen. It is very soluble in water, has a disagreeable odor, and a slightly saline astringent taste, reddens vegetable colors, and causes a purple stain on the skin. Treated with alkalis, alloxanic acid is formed; but on boiling it is decomposed into urea and mesoxalic acid. Heated with per-

oxide of lead, it is decomposed into urea and carbonate of lead, with which a few traces of oxalate of lead are mixed. When brought into contact with zinc and hydrochloric acid, with chloride of zinc or sulphuretted hydrogen, alloxantine is produced; it is decomposed by free ammonia into mykomelinic acid, by nitric acid into parabanic acid, by sulphuric and hydrochloric acids into alloxantine, by sulphurous acid and ammonia into thionurate of ammonia, with alloxantine and ammonia into murexide. With a protosalt of iron and an alkali, it forms an indigo-blue solution. Does not unite without decomposition with the metallic oxides. Alloxan is formed from alloxantine by oxidizing substances, and alloxantine is formed from alloxan, by deoxidizing substances.

Formation. The formation of alloxan and the other products which arise at the same time, is dependent upon two perfectly independent decompositions; namely, upon the conversion of cyanoxalic acid into alloxan, and upon the mutual decomposition of urea and nitrous acid. To 1 eq. of cyanoxalic acid are added the elements of 4 eq. water, and 2 eq. oxygen from 1 eq. nitric acid, by which 1 eq. alloxan and 1 eq. nitrous acid are formed. The latter combines with the ammonia of the urea, and liberates cyanic acid; the nitrite of ammonia is decomposed by heat into nitrogen and water, and the cyanic acid with water is resolved into carbonic acid and ammonia, which unites with the free nitric acid.



$\text{NO}_3 +$
Nitrous
acid.

$\text{C}_2\text{NO} +$
Cyanic
acid.

HO
Water.

The nitrite of ammonia $\text{NH}_3, \text{NO}_3 = \text{N}_2 + 4 \text{ HO}$; and the cyanic acid C_2NO , with 3 eq. water, 3 HO, yields 2 eq. carbonic acid, 2 CO_2 , and 1 eq. ammonia, NH_3 . If to the products above mentioned we add alloxantine and parabanic acid, which may be formed by the action of nitric acid on alloxan, the results of this complicated reaction are all clearly accounted for. They are alloxan, alloxantine, parabanic acid, nitrate of ammonia, carbonic acid, and nitrogen. Under certain circumstances nitrate of urea is also formed.

It frequently happens that on dissolving the impure alloxan for the purpose of purifying by a second crystallisation, a portion of alloxantine is obtained; it may be easily separated from the alloxan by cold water. See ALLOXANTINE. (*Liebig's Turner.*)

ALLOXANATES. *Chem.* Alloxanic acid neutralizes the alkalis perfectly, decomposes the carbonates, and forms, when neutralized by ammonia, with the salts of silver, a white precipitate, which, by boiling, becomes first yellow and then black, the change being accompanied by a rapid effervescence; treated with ammo-

nia in excess, it produces white gelatinous precipitates with the salts of lime, strontia, and baryta; but the precipitate is redissolved by a large excess of water, and readily by an acid. The solutions of the neutral alloxanate of lime, strontia, and baryta, become turbid when boiled, the bases are precipitated, and urea and mesoxalic acid are formed.

Alloxanate of Baryta. Formula, $\text{C}_8\text{N}_2\text{H}_2\text{O}_8, 2 \text{ BaO} + 8 \text{ aq.}$ Prepared by adding barytic water to an aqueous solution of alloxan at the temperature of 140° ; on each addition a white precipitate is formed, but it is redissolved by stirring; the barytic water is added in successive portions till the precipitate is permanent, when the solution is allowed to cool. The mother-liquor separated from the crystals is again to be heated and treated with barytic water as before, and this should be repeated as long as crystals are obtained.

Short transparent needles, or mother-of-pearl scales, which at 212° become milk-white and lose 3 eq. water; at 300° they are anhydrous; they are sparingly soluble in cold, but more freely in hot water; exposed to a red heat they

ALLOXANIC ACID.

leave a mixture of carbonate of baryta and cyanide of barium.

Alloxanate of Silver. Formula, $C_8N_2H_2O_8 + 2 AgO$. A white insoluble powder, which produces a slight explosion when heated; the residue after being heated to redness yields cyanic acid and metallic silver. (*Liebig's Turner.*)

ALLOXANIC ACID. *Chem.* Discovered by Wöhler and Liebig, in decomposing alloxan by alkalies.

Formula, $C_8H_5N_2O_8 + 2 HO$.

It is prepared by decomposing alloxanate of baryta by sulphuric acid. A strongly acid fluid is obtained, which by gentle evaporation

ALLOXANTINE.

crystallises in radiated groups of acicular crystals; it is a bibasic acid, dissolves zinc, with the evolution of hydrogen, is unchanged by sulphuretted hydrogen, and precipitates the salts of silver, baryta, and lime. The anhydrous alloxanic acid contains the constituents of alloxan minus 2 eq. water; and the hydrated acid has the same composition as anhydrous alloxan. (*Liebig's Turner.*)

ALLOXANTINE. *Chem.* First observed by Prout as a product of decomposition of uric by nitric acid; also formed by the action of chlorine on uric acid, and by the action of deoxidizing substances on alloxan.

	Formula, $C_8H_5N_2O_{10}$		Calculated.	Found.
	H = 1	O = 100		
8 eq. carbon	48	600.96	30.16	30.339
5 " hydrogen	5	62.50	3.06	3.200
2 " nitrogen	28.4	354.08	17.46	17.669
10 " oxygen	80	1000.00	49.32	48.792
	161.4	2017.54	100.00	100.000

Prep. From uric acid: one part of uric acid is added to 32 parts of water, which is brought to the boiling point, and then treated with dilute nitric acid in successive portions till a perfect solution is obtained; it should then be evaporated to two-thirds of its volume, when, after standing for some hours, or a day, crystals of alloxantine will be deposited, which should be purified by recrystallisation.—*From alloxan:* it is obtained in large quantity by transmitting a stream of hydrosulphuric acid gas through a solution of alloxan, when first sulphur, and then a crystalline mass of alloxantine is deposited; it is separated from the sulphur by solution in hot water, which yields by evaporation and cooling pure crystals of alloxantine. It may also be formed by adding zinc and hydrochloric acid to a solution of alloxan, but here an excess of acid must be carefully avoided; or by boiling alloxan in moderately strong sulphuric acid, when it is deposited as the solution cools. Diluted hydrochloric acid, and even diluted nitric acid, produce the same effect. The latter fact is curious, because stronger nitric acid reconverts alloxantine into alloxan; and also because the conversion of alloxan into alloxantine is a process of deoxidation. The reaction, in this mode of preparation, however, is different from that which occurs when sulphuretted hydrogen is employed. It is explained below for sulphuric acid, and the explanation applies to nitric and hydrochloric acids. (*Gregory.*) If a solution of alloxan be exposed to the action of a galvanic battery, oxygen is evolved at the positive electrode, while the negative is covered with a crystalline crust of alloxantine.

Prop. Short, oblique, four-sided prisms of the oblique prismatic system, the obtuse angle of the prism being 105° . The crystals are colorless, or have a slightly yellow tint; in an ammoniacal atmosphere they become red, acquire a greenish metallic lustre, and are readily reduced to powder; exposed to 212° they undergo no change of weight, but at 300° lose 15.4 per cent.=3 eq. water; sparingly

soluble in cold, more freely in boiling water. The solution reddens litmus; is converted into alloxan by being warmed with strong nitric acid, or by a solution of chlorine; forms with the salts of silver a black precipitate of metallic silver; it is decomposed by alkalies; barytic water causes a violet-blue precipitate, which is first rendered colorless by heat and then disappears; by adding an excess of baryta to this solution, a brilliant white precipitate is formed.

Formation. By the action of dilute nitric acid upon uric acid, only 1 eq. of oxygen is taken up by the cyanoxalic acid, and there is formed by the addition of the elements of 5 eq. of water, 1 eq. alloxantine and nitrous acid, which is decomposed by the water into $\frac{1}{2}$ eq. of nitrous acid, and $\frac{1}{2}$ eq. nitric acid; the former reacts as described in alloxan upon half of the urea liberated, causing their mutual decomposition, while the other half of the urea combines with the nitric acid to nitrate of urea. In its preparation from alloxan 1 eq. oxygen of the latter is converted, by the hydrogen of the sulphuretted hydrogen, into water, which remains in combination with the other elements. On boiling alloxan with sulphuric acid, 2 eq. are decomposed into 1 eq. alloxantine, 3 eq. oxalic acid, 1 eq. ammonia, and 1 eq. cyanic acid; the latter being decomposed, together with 3 eq. water, into carbonic acid and ammonia. If a solution of alloxan, instead of being left in contact with zinc and hydrochloric acid at common temperature, be heated to the boiling point, and kept at that temperature for some time, it deposits, on cooling, yellow granular crystals, of a brilliant lustre and sparing solubility in boiling water, and of characters essentially different from alloxantine.

Products of the Decomposition of Alloxantine. If a stream of sulphuretted hydrogen gas be passed through a boiling solution of alloxantine, a further precipitation of sulphur ensues, and the solution acquires a strongly acid reaction; if neutralized by carbonate of ammonia, it deposits on cooling an abundant crop of white

silky acicular crystals of an ammoniacal salt, which, when heated to 212° in the air, becomes of a blood-red color; its composition is represented by the formula $C_8N_3H_7O_8$, and it may therefore be considered to be a compound of cyanoxalic acid with 1 eq. ammonia and 4 eq. water. The acid in this salt, when we attempt to separate it from the ammonia with which it is combined, appears to be decomposed into a variety of new products. It is proposed to call this acid the Dialuric acid, since its properties appear to differ from those of the cyanoxalic. It is probable that the dialurate of ammonia may be $C_8N_2H_3O_7 + NH_4O$. If this be so, the anhydrous dialuric acid will be $C_8N_2H_3O_7 = C_8N_2O_4 + 3HO$; that is, containing the elements of 1 eq. cyanoxalic acid and 3 eq. water. One of the products of its decomposition is obtained by dissolving the ammoniacal salt in dilute sulphuric or hydrochloric acid, and exposing it to the air for some time; it crystallises from this solution in hard colorless crystals, which in their chemical properties entirely coincide with alloxantine, but differ from it in their crystalline form; it may be called dimorphous alloxantine. The same substance is formed when uramile or uramile acid is heated with dilute sulphuric or hydrochloric acid until perfectly decomposed.

If a hot saturated solution of alloxantine be treated with a solution of sal-ammoniac, it instantly acquires a purple-red color, which disappears after a few moments, while the solution becomes turbid, and deposits brilliant white scales of uramile, which are pink when dried; the same occurs with the acetate, the oxalate, and other ammoniacal salts; the solution contains, after the decomposition, alloxan and free hydrochloric acid. Two eq. alloxantine and 1 eq. ammonia contain the elements of 1 eq. uramile, 1 eq. alloxan, and 4 eq. water. By heating a solution of alloxantine in pure ammonia, the products first formed are uramile and mykomelinate of ammonia, both of which suffer further changes by the continued action of ammonia and the atmospheric air. If a solution of alloxantine in ammonia, which has been prepared in the cold, be spontaneously evaporated by exposure to the air, oxygen is absorbed, and crystals of the oxalurate of ammonia are obtained; 3 eq. alloxantine, 7 eq. oxygen, and 6 eq. ammonia, contain the elements of 4 eq. oxalurate of ammonia and 5 eq. water.

If oxide of silver be heated in a solution of alloxantine, a portion of the former is reduced with effervescence, and the solution contains pure oxalurate of silver. In this reaction 3 eq. oxygen from the oxide of silver decompose 1 eq. alloxantine into 1 eq. water, 2 eq. carbonic acid, and 1 eq. oxaluric acid, which last unites with some undecomposed oxide of silver. Peroxide of mercury is dissolved by alloxantine without effervescence, and the solution appears to contain alloxanate of the protoxide of mercury. A solution of alloxantine by boiling with peroxide of lead is decomposed into urea and carbonate of lead. (*Liebig's Turner.*)

ALLOY. *Tech. Syn. Ger. Legirung. Fr. Alliage.* Alloys are combinations of metals

with each other, formed by fusion. Those of mercury are called amalgams, some of which are formed at ordinary temperatures.

We shall 1st present a theoretic view of their nature; 2d, the composition of the most important; 3d, their general properties; 4th, their chemical behavior; and, lastly, their preparation and uses.

1. *Chemical nature of alloys.* From the homogeneous character of alloys containing very different proportions of the metals, such as tin and lead, as well as from the slight change of properties often observable, we might conclude that they were capable of mingling together in all proportions, like alcohol and water, but a closer examination shows that, in many cases at least, they are united in equivalent quantities. Thus, the crystallised native amalgam of silver is found to consist of 2 eq. of mercury, and 1 eq. of silver. Now, when silver is amalgamated with mercury, there appears to be no limit to the number of amalgams formed, but by pressing them through leather, there always remains a solid amalgam, which was disseminated through, or dissolved in the liquid mercury. We may compare it to the slacking of lime, in which an eq. of water unites with the lime, and all the excess of water serves to dissolve the hydrate.

There is an amalgam of lead, which is likewise capable of crystallising, and which appears under favorable circumstances, as when a solid syphon of lead is employed to extract mercury from a vessel, there is finally left a crystalline aggregation of the amalgam. (*J. Henry.*)

The experiments of Rudberg, to determine the latent heat of some metals, from their times of cooling, when heated, led him to a remarkable result with certain alloys. (*An. de Ch. et Ph. xlviii. 363—371.*) In whatever proportion the 2 metals, lead and tin, were mingled, there was always one point where the thermometer remained stationary for a time, at 368.6° ; while in all but one alloy, there was another stationary point, which varied with the proportion of the metals, and was near the fusing point of the predominating metal. The latter point is caused by the congelation of the predominating metal; the former constant point is the temperature at which an alloy congeals of definite composition. This alloy is composed of 1 eq. lead + 3 eq. tin ($PbSn_3$). The constant point with alloys of bismuth and tin was 289.4° , the crystallising point of an alloy Bi_2Sn_3 , or perhaps $BiSn$; of the alloys of zinc and tin 399.2° , indicating an alloy $ZnSn_6$; for alloys of lead and bismuth, the point was 264.2° , indicating between $PbBi$ and $PbBi_2$, or probably Pb_3Bi . From which it appears that there is a chemical alloy, and that all others are mixtures of it with one of the metals.

The same facts were observed in relation to three metals, indicating their chemical union; thus, with bismuth, lead, and tin, in any proportion, this point is 208° , but instead of one there are two variable points.

The Svanbergs continued Rudberg's experiments with 3 metals, zinc, lead, and tin, and found the constant point at 334.4° , which belonged to a compound of 1 eq. zinc, 2 eq. lead

and 9 eq. tin; it may be represented by the formula $\text{ZnSn}_3 + 2\text{PbSn}_3$.

The greater fusibility of alloys in certain proportions, points out chemical union; thus, the alloy of BiSn, just mentioned, fuses at 289.4° , the most fusible of all alloys of bismuth and tin; 1 eq. lead + 1 eq. tin, fuses even at a lower temperature than tin itself, as indeed many of these alloys. Kupfer determined the fusing points of different atomic mixtures of tin and lead, which were as follows: PbSn_5 at 381.2° , PbSn_4 , 372.2° , PbSn_3 , 366.6° , PbSn_2 , 384.8° , PbSn , 465.8° , Pb_3Sn , 552.2° ; from which it appears that PbSn_3 , the most fusible, is the chemical alloy found by Rudberg. (See above.)

Experiments made at the United States mint, by Mr. J. R. Eckfeldt, on the progressive alloys of gold and copper, from 1000 milliemmes to pure copper, exhibited a superior brittleness, and a marked crystalline structure, when the alloy contained 760 milliemmes gold (76 per cent.), and that it became more malleable and less crystalline, as it contained more gold or copper. Now, the proportions, 76 to 24, are in the ratio of 199.2 (1 eq.) gold to 62.45 (2 eq.) copper, for 2 eq. copper are exactly 63.42. The chemical alloy of gold and copper is therefore Cu_2Au .

If there be a chemical union in certain alloys, they should evince the ordinary phenomena of affinity. Thus, they should sometimes give off heat by union, which is observed in alloying zinc and copper to form brass, and in many other cases. A few cases are cited where the temperature falls, as when 21 lead, 12 tin, 28 bismuth, and 161 mercury were mingled at 57° , the temperature fell to 16° , but this may be explained on the union of a part of the mercury with the others, producing heat, and forming a solution of these chemical amalgams so as to neutralize the heat, and even produce the cold of solution. Manganese and copper unite, forming a ductile alloy, but we cannot readily reduce the oxide of manganese alone by carbon; when, however, their oxides are mingled with charcoal, and heated, the reduction of the copper induces that of the manganese by virtue of the affinity of the two metals. (See *circumstances, &c., of combination under AFFINITY*.) Where one of the metals in an alloy is volatile, and the other much more fixed, heat may expel a part of the volatile metal, but not the whole of it, showing that there is a sufficient force of affinity to resist the rending force of heat. Copper in brass retains as much as 16 per cent. zinc at a white heat.

We have presented some 6 or 7 alloys of a decided chemical character, and might mention others from which we could infer a chemical union. We cannot, however, determine with certainty, whether all metals are capable of forming alloys, since the combinations of metals with each other have received too little attention from chemists; but as some are undoubted chemical combinations, we may infer that all may unite chemically, and even in different proportions. There is no doubt that metals have different affinities for each other, some being strong, others very feeble. In the former we shall be able to determine the chemical alloy or alloys without much difficulty, while the latter will appear rather like mixtures of 2 metals, like alcohol and water.

There are a few alloys where one metal so greatly predominates over the other, that we might regard the latter as an accidental constituent, remaining in the other by adhesive force (*Berthier*), but the properties of the dominant metal are so much altered, that we must infer a chemical union. Thus, 3.5 per cent. carbon alters the malleability of iron, although in the ratio of 6 eq. iron to 1 eq. carbon, and the presence of magnesium and calcium in cast iron produces a very brittle metal. Karsten says, that only the $\frac{9}{1000}$ of 1 per cent. calcium imparts bad qualities to iron. Iron containing 7 per cent. manganese is very brittle, large lamellar, white and brilliant. Copper, with 8 or 10 per cent. tin (bronze), is heavier and more fusible than copper, much more hard and tough, and very slightly malleable. We may then draw the conclusion that, even when small quantities of one metal are in alloy, there is a chemical combination, and consequently in definite proportions.

2. *Composition of useful alloys.* Of more than 40 metals, we employ but 11, two or more of which united, constitute a much greater number of useful alloys. These metals are, iron, zinc, nickel, bismuth, antimony, lead, copper, tin, mercury, silver, and gold. The following tables comprise most of the useful alloys, with their composition expressed in 100 parts. We have preferred throwing them into several classes, according to their prevailing character or constituent. It must be observed that the proportions of most of them vary, since this may be often done without materially affecting their external and useful properties, and indeed the proportions are varied to adapt them better to special purposes.

Alloys of Precious Metals.

Gold.	Silver.	Copper.	Other Metals.	Spec. Grav.	Name of Alloy.
90	—	10	—	17.20	Coin.
90	2.5	7.5	—	17.40	Coin of United States.
91.6	—	8.4	—	17.41	Medals.
75	—	25	(Silver)	14.78	Trinket gold.
66.6	16.7	16.7	—	12.40	Solder for 18 carats gold, in which the 66.6 is 18 car.
90	—	10	—	10.24	Coin.
95	—	5	—	10.31	Medals and finest silver plate.
66.6	—	23.4	10.0 zinc	9.84	Solder for silver of 95 pr.ct. pure.
66.6	—	30	3.4 brass	9.87	Silver solder.

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Alloys of Mercury or Amalgams.

Mercury.	Tin.	Bismuth.	Other Metals.	Name of Alloy.
90	—	—	10 gold	Amalg. for gilders.
85	—	—	15 silver	Amalg. for silvering.
80	—	20	—	Silvering glass-globes.
50	25	—	25 zinc	Amalg. for electric machines.
30	70	—	—	Amalg. on mirrors.
9	17	45.5	28.5 lead	Alloy for plugging teeth; fuses at 149°.

Alloys of Copper, Zinc, Tin, &c.

Copper.	Zinc.	Tin.	Lead.	Other Metals.	Spec. Grav.	Name of Alloy.
85	15	—	—	—	—	Tombac.
75	25	—	—	—	—	Prince's metal.
70	30	—	—	—	8.443	Brass adapted to hammering.
66	32	—	2	—	8.5 (?)	Brass adapted to the lathe.
67	33	—	—	(or more copp.)	—	For brazing iron.
50	50	—	—	—	—	Brass solder.
60	25	—	—	15 nickel	8.48	Argentan or German silver.
50	25	—	—	25 nickel	8.57	Fine quality argentan.
55	17	—	—	{ 23 nickel } { 3 iron }	8.56	Chinese packfong (argentan).
78	17	2.5	2.5	—	—	Ordinary bronze (brass).
80	6	10	4	—	—	English bells.
71	2	26	—	1 iron	—	Silver bell at Rouen, France.
75	—	25	—	—	8.83	Good average bell composition.
90.5	3	6.5	—	—	—	Imitation of gold.
91.4	5.5	1.7	1.4	—	8.482	Bronze statue of Louis XIV.
80	—	20	—	—	8.8	Statue bronze.
80	—	20	—	—	8.94	Gong, cymbals.
92	—	8	—	—	8.6205	Bronze medals.
90	—	10	—	—	8.78	Cannon metal.
89.3	2.2	6.8	—	1.2 iron	8.60	ditto. (J. C. B.)
85	—	14	—	1 iron	—	Ancient Egyptian sword.
62	—	32	6	—	—	Ancient mirror.
66.5	—	33.5	—	—	8.8 (?)	Speculum metal.

Alloys of Lead, Tin, &c.

Lead.	Tin.	Bismuth.	Antimony.	Other Metals.	Spec. Grav.	Name of Alloy.
80	—	—	20	—	9.854	Type metal.
77	—	8	15	—	—	ditto.
67	33	—	—	—	9.5535	Soft solder.
33	67	—	—	—	8.2669	ditto.
31	19	50	—	—	—	Fusible metal; fuses at 203°.
34	19	47	—	—	—	ditto.
9	75	8	8	—	—	Queen's metal.
Cop. 2	89	Iron 1	6	2 brass	—	Britannia metal.
	89	2	7	2 copp.	—	Plate pewter.
	80	—	20	—	7.1	Music metal.
26	62.8	—	8	3.2 iron	—	ditto. (J. C. B.)
	50	—	—	50 zinc	—	Spurious silver leaf.

3. *Properties of Alloys.*—They resemble metals in their general physical properties, being opaque, possessing metallic lustre, various colors, and conducting heat and electricity; they are solid, with the exception of some amalgams; and some are characterized by a peculiar odor and taste. They are often different in some of their properties from their constituent metals: thus the color of brass is different from copper or zinc, speculum metal from copper and tin. They farther differ in the following important properties:

Hardness. An extremely small amount of silver imparts greater hardness to steel. A

few per cent. tin renders copper very hard, as in cannon metal, and such alloys were anciently employed as weapons and tools in place of steel; silver with 20 per cent. of tin is nearly as hard as cannon metal. With hardness they often gain important additions in sonorousness, as bell metal, the Chinese gong. 60 iron and 40 chrome form an alloy of such hardness as to cut glass as deeply as a diamond.

Tenacity. The malleability of metals is generally impaired by alloying, and usually in proportion to the increase in hardness. Alloys of 2 brittle metals are always brittle, as bismuth with tungsten and manganese. Those of a

brittle and a ductile metal are generally brittle if the former metal predominate; 1 lead and 1 antimony is brittle; bismuth with less silver forms a brittle alloy; on the other hand, copper and manganese form ductile alloys, even with 40 per cent. mangan.; 87 copper + 13 molybdena is ductile.

Two ductile metals sometimes form a brittle alloy: thus 76 gold + 24 copper is rather brittle; gold with $\frac{1}{2}$ of lead and lead with platinum are very brittle; they are usually ductile, as gold and silver coin, copper and zinc in brass, tin and lead in soft solder, copper, zinc, and nickel in German silver.

Alloys are often less ductile at a high than a low temperature: thus, iron containing a little copper is malleable when cold, but brittle at a red heat, and is called hot-short. Brass (copper and zinc) becomes brittle at a somewhat elevated temperature, and the effect in this case seems due to the fusibility of the zinc and its consequent tendency to separate, or to a common effect of heat to impair chemical affinity.

Density. The spec. grav. of an alloy is usually either greater or less than the mean density of its constituents, that is, there is either contraction or expansion, a common effect of chemical union. Gellert and Kraft give as the results of some of their experiments the following contractions and expansions.

Alloys of greater Spec. Grav. (Contraction.)

Gold with	Silver with	Copper with	Lead with
Silver	Copper	Tin	Zinc
Lead	Lead	Zinc	Bismuth
Bismuth	Tin	Antimony	Antimony
Zinc	Bismuth	Mercury with	Bismuth with
	Zinc	Tin	Antimony
	Antimony	Antimony	

Alloys of less Spec. Grav. (Expansion.)

Gold with	Tin with	Iron with	Platinum with
Copper	Zinc	Antimony	Copper
Iron	Lead	Bismuth	
Tin	Antimony	Zinc	Copper and Bismuth neither contract nor expand.
Copper with	Zinc with	Mercury with	
Lead	Antimony	Bismuth	

It will be obvious from this table that the density of an alloy cannot be relied on to determine its constituents.

Fusibility. The fusibility of an alloy is sometimes less than that of the most fusible metal which it contains; sometimes it is more. It is almost always more fusible than the mean fusibility of its constituents. Thus, fusible metal (see the above tables of alloys) melts below 212° , while the mean of the melting points of the 3 metals is 510° ; and tin, which has the lowest point of fusion, melts at 442° . Alloys of copper and zinc (brass) fuse at a lower point than copper.

The union of 2 pieces of metal by soldering depends in part on the differing fusibilities of the metal and solder, the latter requiring a lower temperature for fusion.

4. *Chemical behavior of Alloys. Eliquation.* Alloys composed of 2 unequally fusible metals are either wholly or partially separated by a heat sufficient to melt the most fusible, which process is termed eliquation. Thus, tin may be separated from copper, and in casting this alloy, there is often separated a more fusible alloy with a large proportion of tin. Lead is thus separated from copper on a large scale, carrying with it a little copper, while the latter retains a little lead. Silver is separated from copper by adding a large proportion of lead to the alloy, which, acting by its superior affinity for the silver, flows out with the latter.

Where a volatile and fixed metal are alloyed, eliquation takes place by volatilization; thus mercury is wholly separated from gold by distilling the amalgam. Brass heated in close vessels yields up a portion of zinc, but at a strong white heat it still retains 16 per cent., and at a still higher heat there remains 3 or 4 per cent. with the copper.

Oxidation. Where an alloy is calcined in the air, the more oxidable metal oxidizes first. Tin and lead may thus be separated more perfectly from copper, their oxides carrying off a portion of oxidized copper, but the latter metal finally remains pure. The alloy of lead and silver (see *Eliquation*, above) is rendered absolutely free from lead by cupellation, in which the lead, oxidized by heating in the air, is partly volatilized and partly absorbed by the cupel.

In most cases alloys are less oxidable than the separate metals. Cannon metal, 90 copper + 10 tin, is less oxidable than copper, but by keeping it fused in contact with the air, the tin will oxidize much more rapidly than the copper. On the other hand, soft solder, 2 lead + 1 tin, or, better, the alloy 3 lead + 1 tin, when heated to a low red heat in the air, burns like a pyrophorus, the oxidation of the two being much more rapid than that of either alone, partly due to the effect of contact and partly to the attraction of their resulting oxides. By the union of an acidifiable metal with one more positive, the latter is rendered more oxidable. Thus, chrome and lead exhibit fire under the action of a file; antimony and iron take fire sometimes spontaneously, and always by the assistance of a little heat; a finely divided alloy of antimony and potassium burns in the air with a kind of explosion. (*Dumas.*) But in the alloy of 60 chrome + 40 iron, the change effected by their chemical union is such that it is not readily oxidized even by nitro-muriatic acid.

When metals are kept in a state of fusion in the air, and stirred, the oxidation is often very rapid, from the large number of particles of the oxidable metal simultaneously brought in contact with the air. We can thus explain the tarnishing of mercury containing small quantities of lead, &c., for the latter metal is exposed in a truly melted state to the action of the air, and hence oxidizes with some rapidity

Action of Chem. Agents. In general we may infer the action of chemical reagents from a knowledge of the composition of alloys, but there appear to be cases of such intimate chemical union that the result differs from anticipation. Sulphur acts generally on one metal before another, nearly according to the order of its affinities. Nitro-muriatic acid acts on nearly all alloys, but we cannot always infer its action from their composition; thus, the alloy of chrome and iron (see above) is slightly attacked by it. German silver, containing 25 per cent. nickel and 50 copper, is as little subject to the action of acetic acid as silver with 20 per cent. copper. Boiling concentrated chlorohydric acid attacks copper containing at least 20 per cent. tin, evolving hydrogen, dissolving the greater part of the tin, and finally a little copper; nitric acid dissolves the copper and peroxidizes the tin.

Testing Alloys. We may readily subject alloys to ordinary chemical analysis by solution and separation, but the dry assay is sometimes more convenient, and sufficiently exact. Chaudet, "*L'art de l'essayeur*," has given some examples of the latter method by the different appearances of alloys and the pure metals on the cupel.

Pure Metals. Tin on the cupel fuses, is covered by a nearly black layer of protoxide, which by peroxidation becomes white, gives off a light vapor, exhibits points of incandescence, and the oxide covering the surface is red in the muffel, on cooling lemon-yellow, and white when perfectly cool. Antimony fuses in a moderately hot cupel, remains brilliant, evolves dense white vapors, dissipates entirely, leaving the cupel coated with a lemon-yellow, which disappears, excepting the reddish tint where the metal lay. Zinc fuses pastily, suddenly inflames with greenish white flame, evolving thick white vapors, forms a cone of oxide around the flame, which is greenish when hot, white and very light when cold. Bismuth fuses in a warm cupel, is coated with oxide, which also melts, partly vaporizes in thick vapors, partly enters the cupel, which when cold has an orange-yellow color in some parts and greenish in others. Lead melts in a hot cupel, is coated with oxide, which fuses and leaves the surface very brilliant, vaporizes until the rest enters the cupel; when nearly cool the cupel has a fine lemon-yellow color, which is very pale after some hours, when the metal is pure, but if copper be present, there are greenish zones.

Alloys. An alloy of tin and antimony submitted to the cupel is coated with black oxide, which when cold is blackish gray, unlike pure tin. Tin with 5 per cent. antimony still exhibits a gray instead of white like pure tin; and antimony with 1 per cent. tin leaves a visible quantity of oxide of tin. Tin and zinc, with 20 per cent. of the latter, exhibits the inflammation of zinc, particularly when the alloy is rolled thin, and stirred on the cupel; it gives a light greenish oxide while warm, but white when cold; less than 5 per cent. zinc may be detected; with 1 per cent. zinc the incandescence of pure tin is not observed. Tin with 25 per cent. bismuth exhibits incandescence, and the oxide

when cold is somewhat yellow; with 5 per cent. it was grayish. Tin with 10 per cent. lead resembles tin on the cupel, but the latter is soon thrown on the sides of the cupel, and the lead remains brilliant; it is absorbed, and oxide of tin remains, of a yellowish and brownish color when cold; lead with 1 per cent. tin is not so brilliant as lead, but shows a coating of oxide of tin.

Chaudet believes that the color of alloys, their ductility, sonorousness, spec. grav., their behavior on the cupel, and the color of their oxides, are important means of determining the nature of the metals they contain. There is no doubt of their value in assisting in qualitative analysis, where experience has been already attained; but there are so many chemical means, particularly in the liquid way, of testing the nature of metals and determining their quantities in alloys, that we are inclined to attribute a much higher value to them. Moreover, in many cases these tests are more easily and quickly applied, and their cost is so trifling that it is generally better to resort to them. Many blowpipe tests are most readily used, and sometimes more satisfactorily than any others, in qualitative examinations.

5. *Preparation.* Alloys are formed by fusing the metals together, or at least by having one in a liquid state. Where one of them is volatile and oxidable, some care is requisite to prevent its loss; thus, in making brass, slips of copper are introduced into zinc at a lower heat; the copper tending to detain the latter metal, the heat is raised and more copper added. When a metal tends to oxidize, it should be covered with carbonaceous matter to prevent this result, as, in fusing alloys of tin and lead, grease or rosin is melted on the surface; or on a large scale, as in melting bronze, the surface of the metal is strewn with small charcoal or coke, and the zinc and tin put in last and thrust beneath the copper.

Where the metals are of different specific gravities, or where a larger quantity of one is employed than the other has a marked affinity for, there is a tendency in the two to separate into two alloys, the heavier sinking below the other. Thus gold tends to separate from silver. Even when cast, if the mass be large and the cooling too slow, the same tendency is observable, especially where they are cast upright. In casting cannon, a lighter alloy, containing a larger percentage of tin, is often ejected during the congelation of the mass. In cases where a separation takes place, in order to obtain a more homogeneous alloy, it is necessary to break up the mass, remelt and recast it.

If one metal be volatile, the other may be alloyed with it by exposure to its vapors; plates and rods of copper may be thus coated with a true brass and of fine quality by exposing them to vapors of zinc; and these may be rolled, beaten, or drawn into foil or wire. Vapors of mercury attack gold with facility.

Alloys may also be formed by using one or both metals in the state of oxide. Brass was formerly made exclusively from metallic copper and the oxide or carbonate of zinc (calamine), by mingling charcoal with the oxide, which reduced it to the metallic state. Man

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ganese is often obtained alloyed with iron, in the reduction of iron ores, and the reduction of the iron facilitates that of manganese, which is very difficult of reduction alone.

A few alloys are made in the moist way. Copper may be brassed externally by boiling it in muriatic acid containing argal and zinc-amalgam.

6. *Uses.* Every alloy, as far as regards its utility, may be regarded as a new metal, since alloys possess the usual external properties of metals, beside many others which do not belong to the simple metals. By the addition of different quantities of zinc to copper, we obtain several different alloys, which vary from a light to a dark yellow in color, varying in other properties also; by a small quantity of lead, brass is better adapted to the lathe than without it. A small proportion of the soft metal, tin, imparts an unlooked-for degree of hardness to another soft metal, copper, while the alloy possesses a high degree of toughness, as in cannon; a little more tin, with or without zinc, affords a metal of unusual clearness of tone, as in bells, while copper has little, and tin no sonorousness. A small proportion of mercury renders gold, the most ductile of metals, brittle. The red color of copper is whitened by the addition of silver, zinc, or tin. Silver, which is rather too soft for constant usage, is rendered harder by the addition of copper. Lead was first employed for type, being economical and readily fused, but the types could not take the exact form of the mould, and were too easily abraded; by the addition of antimony it is easily fused, takes an accurate impression from the matrix, is rendered harder, and wears a much longer time. Bismuth, lead, and tin, the latter of which is the most fusible and melts at 442°, form an alloy which fuses in boiling water. Copper, which is easily oxidized in the air in contact with weak acids, loses a great part of this property when alloyed with zinc and nickel, as in German silver.

The practice of soldering depends on the greater fusibility of some alloys. The solder is sometimes of the same composition as the metal to be united, but more fusible. Thus, if two pieces of brass are to be soldered, brass is used, that is, a brass containing more zinc. Silver plate is united by a similar alloy of silver and copper, but containing zinc. Sometimes the solder has a different composition, as when pieces of iron are united by a brass rich in copper.

By examining the alloys in the above tables and comparing their properties with those of the metals generally, it will be seen how much we have gained by the union of metals with each other, how many new metals endowed with new properties. When we remember that out of 11 metals there are formed some 30 or more alloys, what may we not hope for when this subject shall have received its due attention at the hands of the chemist; when the alloys of some 30 or 40 metals with each other shall have been investigated, not only the results produced by the union of 2 metals with each other, and that in every varying proportion, but the character of alloys of 3 or more metals in differing ratios. See the articles

AMALGAM, BRASS, BRITANNIA METAL, BRONZE,

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COIN, FUSIBLE METAL, GERMAN SILVER, MUSIC METAL, PEWTER, SOLDER, TYPE, and the various metals for less useful alloys.

ALLSPICE. *Ger.* Nelkenpfeffer. *Fr.* Girofle. The dried green fruit or berry of the *Eugenia pimenta* (*De Cand.*), growing and cultivated in the West Indies. The following analyses are by Bonastre and Braconnot.

Bonastre.	Husks.	Kernels.
Volatile oil	10.0	5.0
Green soft resin.....	8.4	2.5
Solid fat oil	0.9	1.2
Astringent extract.....	11.4	39.8
Gum	3.0	7.2
Coloring matter.....	4.0	8.8
Resinous matter	1.2	3.2
Uncrystallisable sugar....	3.0	8.0
Malic or gallic acid	0.6	1.6
Lignin, &c.	50.0	16.0
Saline ashes	2.8	1.9
Water	3.5	3.0
Loss.....	1.6	1.8
Total	100.0	100.0

Braconnot.	
Volatile oil	1.9
Amylum.....	9.0
Wax, with red coloring matter	0.9
Gum	6.0
Nitrogenous matter	5.0
Citrate of potash	6.0
Phosphate of potash and loss.....	3.4
Insoluble matter	67.8
Total	100.0

Berzelius notices evident errors in Bonastre's analysis, that what he terms green oil is a mixture of fixed oil, resin, and chlorophyll. The astringent matter or pimento-tannin is soluble in alcohol, strikes a green color with the salts of iron, and precipitates tartar emetic.

The volatile oil is obtained by distilling the bruised allspice with water; 8 cwt. yielded 41 lbs. oil, or nearly 6 per cent. It is composed of 2 oils, the light and heavy, the former coming over first. The common oil of pimento is a mixture of them. Excepting in its odor, its properties are almost identical with those of oil of cloves. By distilling with caustic potassa, the light oil passes over, and by distilling the residue with sulphuric acid, the heavy is obtained.

Light Oil. (Pimento Hydro-carbon.) Similar to light oil of cloves; floats on water and solution of potassa, and is slightly reddened by nitric acid. Potassium sinks in it and is not acted on by it.

Heavy Oil. (Pimentic acid.) Very similar to caryophyllic acid; forms crystalline compounds with alkalies, which become blue or greenish on the addition of tincture of chloride of iron. Nitric acid acts violently on and reddens it. (*Pereira.*)

Allspice is used to flavor and to assist in preserving food and liquids. The oil is rarely employed in medicine, its action being similar to that of cloves.

ALMANDINE.

ALOES.

ALMANDINE. *Min.* See GARNET.

ALMANDINE RUBY. *Min.* See SPINEL.

ALMOND. *Syn. Ger.* Mandel; *Fr.* Amande.

The drupe (nut) of the *Amygdalus communis*, from Barbary and Syria, and cultivated in the south of Europe, of which there are 5 varieties. (*De Cand.*) They are usually distinguished as sweet and bitter almonds (*Ger.* Bittermandel, *Fr.* Amandes ameres).

Sweet almonds were analyzed by Boullay and others, the bitter by Vogel (*Berz. Lehrb.* vii. 513.)

Sweet Almonds by Boullay.

Fixed oil.....	54.0
Emulsin	24.0
Uncryst. sugar.....	6.0
Gum.....	3.0
Woody fibre.....	4.0
Seed pellicles.....	5.0
Water.....	3.5
Acetic acid.....	0.5
	100.0

Bitter Almonds by Vogel.

Fixed oil, by pressure.....	28.0
Emulsin	30.0
Uncryst. sugar	6.5
Gum	3.0
Woody fibre.....	5.0
Seed pellicles.....	8.5
Loss in water,	} ... 19.0
Fixed and volatile oil, &c. }	
	100.0

The important constituents are fixed oil and emulsin in both varieties, and amygdalin and volatile oil in the bitter almond.

Fixed Oil. Obtained by expressing both sweet and bitter almonds, usually the former, from the greater value of the residual cake; they yield on an average 50 per cent. oil. It has a slightly yellowish tint, becoming paler in sun light; is inodorous, and has a mild, oily taste; congeals at a lower temperature than olive oil; spec. grav. 0.911 to 0.920. It consists of 76 oleine and 24 margarine. (*Braconnot.*) It is soluble in ether, in 6 boiling, and 25 cold alcohol.

Emulsin is an albuminous substance. *Amygdalin* is a crystallizable constituent of the bitter almond (discovered subsequent to the above analyses) which is converted by the presence of emulsin and water into the volatile oil and hydrocyanic acid. See AMYGDALIN and EMULSIN.

Volatile Oil of Bitter Almonds. (*Ger.* Bittermandelöl.) Obtained by distilling with water, or water and salt, the residual cake of bitter almonds, after expressing the fixed oil. It is highly poisonous, has a golden yellow color, an

agreeable odor, an acrid, bitter taste; burns with a white flame; spec. grav. 1.0836; soluble in ether and alcohol. Sulphuric acid forms with it a thick crimson-red liquid, which by dilution with water gives a yellow emulsion.

Pereira notices 3 kinds of crystalline deposits in this oil, which become severally emerald-green, cherry-red, and lemon-yellow, when dropped into sulphuric acid.

Uses of Almonds, &c. The sweet are employed alone as food, or to impart an agreeable taste to cakes, &c., or by the confectioner. They are also employed medicinally, in an emulsion, or the fixed oil is used. The blanched are preferable, from the irritating action of the pellicles or husks. They are blanched by steeping the kernels in warm water and removing the pellicle.

The bitter almonds are more or less poisonous, probably in consequence of the formation of hydrocyanic (prussic) acid. Their emulsion, distilled water and tincture act similarly, and hence cordials (noyau) flavored with bitter almonds may act injuriously. The volatile oil is highly poisonous. Their principal uses are for pressing to obtain the fixed oil, and subsequently the volatile oil, and for flavoring food. The volatile oil is also employed for the latter purpose, and by the perfumer for toilet soaps, &c. The essence of bitter almonds is applied both to the volatile oil and its solution in alcohol, 1 measure oil to 3 meas. alcohol is a good essence. See *Gmelin*, *Berzelius*, and *Pereira on Almonds*. See also the articles AMYGDALIN, BENZULE, and EMULSIN, in the present work.

ALOES. Bot. Chem. Phar. The inspissated juice of many species of aloe, the 3 principal being *A. vulgaris*, *A. socotrina*, *A. spicata*. The finest kind is obtained from the juice flowing spontaneously from the leaves cut transversely, after dipping the leaves in hot water; an inferior kind by pressure, which contains also mucilaginous matter; and one still inferior by boiling with water the leaves from which the greater part had previously exuded.

Aloes has a very bitter taste, is almost wholly soluble in hot water and alcohol; on cooling the infusion, resin (?) is deposited. The clear solution has an acid reaction, strikes a deep olive brown color with perchloride of iron, is deepened in color by alkalies, unchanged by gelatine. Subacetate of lead forms a copious yellow precipitate.

The proximate composition of aloes has occupied many chemists unsuccessfully, but they generally agree in the existence of a resin, the quantity of which usually varies from 25 to 50 per cent., and in albumen, but the chief constituent is variously designated, as shown in the following tables.

Trommsdorf.			Bouillon-Lagrange, and Vogel.			Braconnot.		Winkler.		
	Soc.	Bar.		Soc.	Bar.		Soc.		Soc.	Bar.
Saponaceous principle	75	81.25	Extractive	68	52	Bitter princ.	73	Bitter matter	50	60
Resin	25	6.25	Resin	32	42	Puce-colored	26	Resin	50	35
Vegetable albumen...	0	12.50	Veg. album.	0	6	Impurities..	1	Albumen	0	5
Gallic acid	trace	trace								
Aloes	100	100		100	100		100		100	100

ALOERESINIC ACID.

Aloesin (see below). The *resin* is the substance deposited from a cooling solution. When dry it is brown, transparent, fusible, soluble in alcohol, ether, and alkaline solutions. Berzelius regards it as apothème with unaltered extract; Braconnot as a mixture of aloesin with his puce-colored principle. The latter is a combustible, odorless, and tasteless powder, obtained by digesting litharge with aloes and water, and decomposing its combination with lead by a weak nitric acid. It is probable that this puce-colored body contains chrysammic acid or a compound of it. The *albumen* is a substance insoluble both in water and alcohol.

Aloes is characterized by its oxidation by nitric acid, which was observed by Chevreul and Braconnot, and more recently by Boutin and Schunck. The residual substance of the oxidation was termed artificial aloebitter, aloetic acid, and polychronic acid. Schunck regards it as a mixture of 2 acids, the aloetic and aloeresinic acid. (See these acids below.) By the action of boiling nitric acid, spec. grav. 1.37, on aloes for several days, Schunck obtained 2 other acids, the Chrysammic and Chrysoplepic, to which refer.

Uses. Chiefly in medicine. Fabroni obtained a fine violet color from the fresh juice of the aloes, which has been proposed as a dye for silk; it is formed by the action of the oxygen of the air on the juice. (*Pereira.*)

ALOERESINIC ACID. *Chem.* One of the acids, according to Schunck, formed by the action of nitric acid on aloes. It is soluble in water; its potassa salt is uncrystallizable; it forms with most bases brownish red insoluble salts. See **ALOETIC ACID**.

ALoesin. *Chem.* Syn. Saponaceous matter, Extractive, Bitter principle. The principal constituent of aloes, obtained by evaporating the aqueous solution of aloes after separating the resin. It is a brown, bitter mass, readily soluble in water, with difficulty in common alcohol; nearly insoluble in absolute alcohol and ether. Its composition is unknown, but it evidently contains nitrogen from the appearance of ammonia among the products of its distillation. It is probably a mixture of several principles.

ALOETIC ACID. *Chem.* Syn. Polychromic acid, Artificial bitter principle of aloes. *Prep.* Heat 1 pt. aloes with 8 pts. nitric acid, spec. grav. 1.25. When the reaction ceases, evaporate to the consistence of syrup, add cold water, which precipitates impure aloetic acid. Purified by washing with water until it passes through the filter of a purple color. *Prop.* When pure, it is a yellow or brown powder, of a bitter and astringent taste; soluble in 800 pts. cold, much more in warm water, with a purple color; the solution has an acid reaction, and is changed to yellow by acids; when heated the powder explodes. According to Schunck its salts are generally soluble; the aloetate of potassa, when crystallized rapidly, forms small blood-red prisms; by spontaneous evaporation, long ruby-red needles.

The boiling solution imparts a deep purple color to silk, and by the use of different mordants, various hues of brown, violet, blue,

ALUM.

green, and yellow are obtained. See **ALOES** and the other products of oxidation by nitric acid.

ALOIN. *Chem.* A name given by Meissner to a supposed alkali in aloes. Its solution was brown, changed reddened litmus, and formed a crystalline salt with sulphuric acid.

ALTHEIN. *Chem.* A principle obtained from *Althæa officinalis*, and identical with **ASPARAGIN**. See this and **MALLOW**.

ALTHIONIC ACID. *Chem.* An acid found in the residue after preparing ether or olefiant gas. (*Regnault.*) *Prep.* When the mixture of sulphuric acid and alcohol, in preparing ether, turns black and begins to froth, neutralize it with milk of lime, filter and evaporate the salt of lime to crystallize; precipitate with oxalic acid, which leaves althionic acid in solution. *Prop.* When the acid solution is boiled, it yields alcohol and sulphuric acid, in which it resembles sulphovinic acid, with which it is isomeric. They were supposed to be the same, but there is a difference in the crystalline form and solubility of corresponding salts of the two acids. *Salts.* Althionates of potassa, lime, and baryta crystallize with difficulty. (The salt of lime does not crystallize. *Kane.*) Althionate of baryta forms fine needles instead of the large plates of sulphovinate; when boiled for a long time, it deposits sulphate of baryta, and if now neutralized with carbonate of baryta, more sulphate is formed, and there remains a small quantity of a soluble salt of baryta not farther examined. Althionate of copper crystallizes in long, thin, rhombic plates, of a pale green color, with an acute angle of 60°. See **SULPHOVINIC ACID** for the composition Althionic Acid.

ALUDEL. *Tech.* A pear-shaped vessel of stoneware, like the **ADOPTER**, fig. 7, a series of which, joined together and luted by clay, constitute the aludel system for condensing mercurial vapors, employed at the mines of Almaden, in Spain, and formerly used in Idria.

ALUM. *Min.* Common alum is a sulphate of alumina and potassa, but the potassa may wholly or in part be replaced by other bases, such as soda, ammonia, &c., which give rise to several kinds of alum which have been found native.

1. *Potassa alum.* Syn. Octahedral alum salt *Ger.* Alaun. *Fr.* Alumine sulphatée alcaline.

Descrip. Crystal. in the regular system, but is usually found fibrous and as an efflorescence. $H = 2-2.5$; spec. grav. 1.75; color and streak white; lustre vitreous, sometimes dull; opaque, translucent; taste sweet, astringent and acid.

Behavior. Fuses in the bulb, swells, gives off much water; at ignition gives off sulphurous acid; the residue gives a pure blue, with cobalt solution. Soluble in 10 to 11 pts. cold and 1 pt. boiling water.

Analysis. Shows that it is composed as common alum (see this), but it is always mixed with sulphate of alumina and other foreign ingredients.

Locality. On alum-slate, alum-stone, &c.; Whitby, in Yorkshire; Christiania, Norway; Tschermig, Bohemia; at volcanoes, Lipari isles &c.; on sandstone, Kentucky, near the Ohio.

ALUM.

2. *Soda-alum.* Syn. Solfatarite. Ger. Natronalaun.

Descrip. Occurs in fibrous masses or crusts resembling gypsum. $H = 2$; spec. grav. = 1.88. Color and streak white; lustre pearly—silky internally and translucent, but opaque externally from efflorescence; tastes like potassa-alum.

Behavior similar to potassa-alum.

Analysis by Thomson, from Mendoza, South America. Sulphuric acid 37.7, alumina 12.4, soda 7.5, water 42.4 = 100. Gruner's analysis of one from South America gives ammonia and no soda.

Locality. Mendoza, South America.

3. *Ammonia-alum.* *Descrip.* $H = 2$; spec. grav. = 1.56. Fibrous; color and streak nearly white; lustre shining, resinous; translucent; taste, &c., similar to the above.

Behavior, similar to potassa-alum, but it yields in the matrass a sublimate of sulphate of ammonia; heated with soda or potassa, gives off ammoniacal gas.

Analysis of am. al. from Tschermig, Bohemia, by Pfaff, Lampadius, Stromeyer, from S. America, by Gruner.

	Pfaff.	Lampad.	Strom.	Gruner.
Sulphuric acid	36.00	38.58	36.065	33.682
Alumina	12.13	12.34	11.602	10.750
Ammonia	6.58	4.12	3.721	3.619
Magnesia	0.28	—	0.115	—
Water	45.00	44.96	48.390	51.000
	100.00	100.00	99.893	99.051

Locality. It occurs chiefly at Tschermig, Bohemia, in lignite.

4. *Manganous Magnesia-alum.* *Descrip.* Fibrous, compact; streak and color white; lustre shining; taste similar to the preceding; more soluble.

Analysis, by Apjohn and Stromeyer.

Potassa	alum.	$\text{KO}_2\text{SO}_3 + \text{Al}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{HO}$
Soda	"	$\text{NaO}_2\text{SO}_3 + \text{Al}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{HO}$
Ammonia	"	$\text{NH}_4\text{O}_2\text{SO}_3 + \text{Al}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{HO}$
Manganous magnesia	"	$\left\{ \begin{array}{l} \text{MgO} \\ \text{MnO} \end{array} \right\} \text{SO}_3 + \text{Al}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{HO}$
Ferrous	"	$\text{FeO}_2\text{SO}_3 + \text{Al}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{HO}$

Now we know that alum is made containing sesquioxide of iron in place of alumina, and hence we may find a native alum of such a composition. The general formula, therefore, for alums is, representing the metals by R (radical) = $\text{RO}_2\text{SO}_3 + \text{R}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{aqua}$.

ALUM. *Tech. Chem.* A most important salt for the arts, especially used in dyeing and color printing, as the chief basis for light and bright colors. We propose presenting under this head the manufacture, properties, and uses of common alum, whether containing potassa or ammonia; and of sulphate of alumina, which is superior to alum in many respects, and may be substituted for it.

I. SULPHATE OF ALUMINA.

Syn. Ger. Schwefelsaure Thonerde. It is procured by the direct action of sulphuric acid on clay, or by the calcination of pyrites in con-

ALUM.

	Apjohn.	Stromeyer.
Sulphuric acid	32.79	36.770
Alumina	10.65	11.515
Magnesia	(sulphate = 1.08)	3.690
Oxide of manganese	7.33	2.617
Water	48.15	45.739
Chloride of potassium	—	0.205
	100.00	100.086

Locality. Covering the floor of a cave 6 inches deep, near Cape Verd, South Africa; the roof is a conglomerate containing manganese and pyrites; it rests on a bed of Epsom salt $1\frac{1}{2}$ inch thick. (*Dana*.)

5. *Ferrous-alum.* Syn. Iron-alum. Ger. Federalaun, Haarsalz, in part. Fr. Alun de plume.

Descrip. Fine fibrous, yellowish white, shining, silky lustre.

Analysis, by Berthier; from Hurlet, by Phillips; from the quicksilver mine of Zweibrücken, by Rammelsberg; the last see in *Pogg. An.* 43, p. 399.

	Rammelsb.	Berthier.	Phillips.
Sulphuric acid	36.025	34.4	30.9
Alumina	10.914	8.8	5.2
Protoxide of iron	9.367	12.0	20.7
Magnesia	0.235	0.8	—
Potassa	0.434	—	—
Water	43.025	44.0	43.2
	100.000	100.0	100.0

Locality. Hurlet, Zweibrücken, Artern, in Thuringen; the mountain butter (Bergbutter) is of the same nature, such as that from Wetzelsstein.

General observations. Although some of these analyses of native alums do not exactly agree with the true composition of all such salts from the admixture of foreign materials, yet there is no doubt that they contain them in due equivalent proportions. Their composition may be represented by the following formulæ.

tact with clay slate; the latter is generally the first step in the preparation of alum.

By direct action. Chaptal and Alban were the first to employ this process.

Calcination. The purest clay is chosen, as free as possible from lime and oxide of iron, which waste the acid. It is calcined in a reverberatory, to expel water and thus render the clay more porous, and more absorbent for sulphuric acid by adhesive attraction, to peroxidize the iron and render it less soluble in acid, and lastly to impair the attraction between the silica and alumina in the clay, and thus favor the action of the acid. If the heat of calcination be too high, the silica and alumina begin to cement together, especially where oxide of iron is present, and oppose a stronger resistance to the action of sulphuric acid. The waste heat of evaporation may be employed. The burned clay is powdered and sifted or

washed over to obtain it in a finely divided state.

Solution. The powdered and calcined clay is put into leaden vessels or stone vats, and for every 100 pts. of it, 45 pts. sulphuric acid of 45° Beaume is poured over it (some use it of 66° B.), and the whole covered. It may be warmed by steam in lead vessels, or by the hot vapors and smoke of the reverberatory, which heats the pasty mass to about 150°—160. It is frequently stirred, and after some days taken out and exposed in a warm and moist situation for a month or more. With a stronger acid than 45° B. less time is required, but there is apt to be an excess of acid. The mass is next mingled with water in vats and suffered to settle; the clear liquor drawn off is from 15° to 18° B. The residue is again treated with water and the weak liquids employed to lixivate fresh material.

The stronger solutions marking 15—18° B., are evaporated to 20° B., drawn off into vessels to cool and settle, when the clear liquor is again evaporated to 40° B., when potassa-alum is to be made; or to 25° only, when sulphate of ammonia is to be added for ammoniac-alum.

If the object be to form crystallized sulphate of alumina and not alum, the strong liquors are simply evaporated to 20° B., drawn off, settled, and the clear liquor evaporated till a pellicle forms on the surface, when it is drawn off into the crystallizers. See the *Uses of alum* for those of sulphate of alumina.

This salt is also made *indirectly* in the process of making alum, by the oxidation of sulphuret of iron in contact with slates and clays.

II. MANUFACTURE OF ALUM.

Syn. Sulphate of alumina and potassa. *Ger.* Alaun. *Fr.* Alun.

1. From *alum-lavas*. An impure alum is obtained at Solfatara, Italy, by collecting an efflorescence of this salt on the surface of the ground, dissolving in water, suffering it to settle, evaporating the clear liquor in lead pans placed in the ground, the temperature of which is 104°, and crystallizing. By recrystallization it becomes somewhat purer, but is still an impure salt, and much material is lost, as the insoluble residue contains basic salts which might be partly converted into alum by sulphuric acid.

2. From *alum-stone*. (See this article for composition and localities). The broken stone is calcined in heaps, in a furnace like a lime-kiln, or in a reverberatory. It is then exposed in heaps or wooden vats to effloresce, and daily moistened with water for several months; the mass gradually sinks and is converted into a paste, above which, is a liquid containing a basic alum. This is heated for several hours in copper or lead vessels, and when cooled and settled the clear liquor is drawn off into the crystallizers. It crystallizes first in octahedra, and lastly in the cube. Re-cryst. purifies it.

Water is without action on the uncalcined stone, as the alum probably exists in it in a very basic and insoluble state. Now, at a temp. below redness, the stone loses its water;

at a red heat the sulphate of alumina is decomposed, and at a white heat the sulphate of potassa (?). Hence, when not heated sufficiently high to expel water and render a portion of alumina insoluble leaving a basic soluble salt, water will not extract all of the alum; when too highly heated a portion of sulphuric acid is lost, and the potassa combines with silica and alumina to an insoluble compound, so that water will then abstract little or nothing. Where calcined in heaps or a kiln, it is difficult so to regulate the heat as to avoid the decomp. of a portion of the salt, and therefore a reverberatory is preferable; in the use of the last, the stone should be very finely broken.

The salt thus obtained is termed *Roman alum*, occurring in small pieces of a flesh color, from the mixture of a little oxide of iron. Dissolved in water and heated below 105°, or by spontaneous evaporation, it yields cubic alum; but when heated to 110° or above, a very basic alum is precipitated, and common alum remains, which crystallizes in octahedra from the filtered solution; but in cubes, if the solution be cooled by contact with the precipitate. It would appear therefore that Roman alum is a basic alum, i. e. contains basic sulphate of alumina + neutral sulphate of potassa.

Uses. It is one of the purest alums of commerce, often containing but .05 of 1 per cent. oxide of iron. On this account, and from its greater content of alumina it is preferred in many operations of the calico printer. The cubic or neutral alum, (see below,) is a good substitute for it. At Tolfa, in the Papal territory there is an annual produce of 5000 tons. It is further procured in Hungary, Auvergne, France, &c.

3. From *alum-slate* and *alum-earth*. In the preceding processes the salt was found ready formed; but in the present, which are the usual processes, the whole or the greater part of it is produced by the oxidation of sulphuret of iron into sulphate of iron, which is converted into sulphate of alumina by the presence of alumina, and a salt of potassa or ammonia added to form the alum. Its manufacture, therefore, falls into *a*, the oxidation of the sulphuret; *b*, the lixiviation; *c*, the evaporation; *d*, the formation of alum; *e*, the crystallization.

a. Oxidation. The alum-earth usually contains a little sulphate of alumina, iron, and potassa. When friable, porous, not bituminous, and containing little sulphuret, the earthy slate is exposed to the action of the air without previous calcination. It is thrown into heaps, under cover or not, and in a dry season moistened with water. The process requires according to the character of the earth from 1 to 2 years; and its completion is known by the strength of lye yielded by a small test portion. This alum-earth evidently contains that variety of pyrites which changes spontaneously in moist air into protosulphate of iron, consisting of 1 equiv. iron + 1 equiv. sulphur, or the magnetic pyrites 6 or 7 iron + 7 or 8 sulphur, which suffers the same change more slowly. There is formed a mixed proto- and sesqui sulphate of iron, which is decomposed by alumina, forming sulphate of alumina and leaving

either sesquioxide or a basic sesquisulphate of iron.

Some alum-earth and the slates contain bituminous matter (coal) and sesqui- or bisulphuret of iron; the latter of which by calcination loses sulphur, and passes into the oxidable protosulphuret; while the former assists combustion, and being burned off, leaves the mass more porous and more pervious to the action of the air. A bed of brushwood or coal is laid on a slightly inclined and packed ground, with a gutter running around it, and the broken slate piled several feet thick upon it and fired. The best method is to give the bed great length, 100 to 150 feet, and a breadth of 6 to 8 feet. At Hurlet, England, when 4 feet of stone is piled on it is fired, and when ignited, more rock thrown on. At Whitby, England, the piling is continued till the heap rises nearly to 100 feet, and its breadth increases to some 200 feet square. The violence of the combustion is diminished by stopping up the crevices with moistened slate or earth. Where the slates contain sufficient bituminous matter, the lower bed of wood or coal is all that will be requisite; where otherwise, it may be necessary to inter-stratify fuel with the slates. The object of the gutter is to collect the liquid in case of rain.

Since pyrites and alumina are the only requisites, the sulphate of alumina is also manufactured from pyrites, and clay or slate. It is thus made at coal mines in the stone-coal formation, at several places in Poland. The fine coal or culm, mingled with slate or clay and pyrites, is thrown into heaps of some 60 feet length, by 10 breadth and 7 height, and fired; as the combustion progresses slowly inward, the ashes on the outside are removed to favor the access of air. When too windy, the side exposed to the wind is to be covered with lixiviated earth; and in a dry summer, the heap is moistened with water. 7 tons produce 1 ton ashes, from which are derived 12 lb. alum.

By calcining common pyrites carefully at a moderate heat, it first loses sulphur, partly as such, and partly as sulphurous acid, and then the oxidation immediately or simultaneously commences, converting the protosulphuret into sulphate; but where the heat is too high, a large proportion of sulphur is lost, and even of sulphuric acid, which has been generated. Now, where the mass is too great, the heat cannot be regulated with the same care, and hence the process at Whitby is less economical than it might be, if otherwise conducted. Again, some slates contain more carbonaceous matter than others, and by their ignition too high a heat might easily be produced. To favor the action of the air in low piles, openings may be now and then made into the heap; in larger heaps this would be inadvisable, since the combustion might become too violent.

According to the extent of the heaps, weeks or months may elapse before the calcination is finished; it is diminished to one-half its original bulk, and is covered with a light reddish ash. The oxidation is known to be complete from the taste of the ashes, from the effloresced salt, or, still better, by the quantity of alum its lixivium yields with sulphate of potassa.

The theory of this process is the same as the preceding, after a part of the sulphur is removed by calcination, viz., that protosulphuret oxidizes into proto- and sesquisulphate of iron, which by contact with the alumina of the slate form the sulphate of the latter. When the heap is fired with brushwood, the theory is a little more complicated, for its ashes, yielding potassa, give rise to the formation of small quantities of alum. One point deserves particular notice, viz.: the formation of sulphuric from a part of the sulphurous acid. In contact with bases, alumina, sesquioxide of iron, potassa, &c., the latter may readily change by oxidation into sulphuric, and this result is undoubtedly hastened by the porous character of the slate, which acts similarly to platinum sponge. See SULPHURIC ACID. The products of calcination are, among other substances, basic sulphates of alumina and sesquioxide of iron, which are insoluble, and the sulphates of alumina, proto- and sesquioxide of iron, with and without sulphates of potassa and ammonia, which are soluble. The ammonia arises from the combustion of coal.

b. Lixiviation. The calcined slate is thrown into a stone or wooden cistern, the former being preferable; water is run on it, and after remaining some time run off into a second cistern on a lower level. The stone in the first is again lixiviated, and the liquor either run into the second or a separate cistern. The water of the third or fourth lixiviation is employed to lixivate fresh portions of calcined mineral. The liquor is thus obtained of spec. grav. 1.08 to 1.15 (10° to 19° B.).

By running off the liquor immediately from the second tank to evaporate, the alum is apt to contain more oxide of iron; it is therefore advisable to suffer it to remain exposed for some time, in order that all the protosulphate may become a basic sesquisulphate, and deposit, together with other insoluble impurities.

c. Evaporation. The clear liquid from the vat or cistern is either evaporated in a stone cistern with a fire built at one end, from which the hot air and smoke, driving across the surface of the liquid, keep it in ebullition and concentrate it; or in leaden pans over a moderate fire. When thus concentrated and suffered to stand, it deposits more sulphate of lime and basic sesquisulphate of iron; the latter being formed during ebullition, from the protosulphate. The degree of concentration must vary with the content of iron, which should be removed, as it deteriorates the quality of alum; it is separated partly as an insoluble sesquisulphate, by boiling, and partly as protosulphate, by crystallization. Thus, it may evaporate to spec. grav. 1.33 (36° B.), to deposit insoluble salts; then run into the crystallizers to obtain the alum ready formed, and again concentrated to 1.4 (42° B.), to remove a portion of copperas; it is again concentrated and crystallized to remove more oxide of iron; if thus treated a third and fourth time, the alum will be nearly free from iron.

Where the content of iron is small, the liquid may be evaporated to a syrupy consistence, from the great solubility of sulphate of alumina, and is then prepared for the forma-

tion of alum. But if it be desired to obtain the sulphate of alumina alone, it should be still farther evaporated until the cooling liquid will solidify.

d. Precipitation. Alum is formed by adding sulphate of potassa or ammonia to the preceding solution. Although alum is soluble in water, it is not extremely so, and hence the addition of a hot saturated solution of sulphated alkali to the above concentrated liquid precipitates alum in fine mealy crystals, leaving the greater part of the salts of iron in solution.

The clear concentrated liquid is run off into the precipitating vat, and a due proportion of carbonate, sulphate, or muriate of potassa, or sulphate or carbonate of ammonia is added to it, with constant stirring, the object of which is to produce powdery crystals, containing but little of the mother liquor, and therefore fewer impurities. The due quantity of salt is ascertained by testing a small quantity of the liquid.

The choice of a precipitant depends upon the prices of the several articles named, and upon the impurities of the aluminous solution. Carbonated alkali may be used when there is an excess of sulphuric acid; for otherwise it would precipitate oxide of iron and alumina with alum; it would not, however, be very objectionable, even in the latter case; for, upon the resolution of the alum-meal, they would mostly remain undissolved. Sulphated alkali is usually preferred, and is superior to other salts, where the aluminous liquor contains little oxide of iron. When the sulphate of iron is somewhat abundant in the liquor, chloride of potassium (muriate of potash) is preferable, since the two are mutually decomposed into sulphate of potassa and chloride of iron; the latter being very soluble, is easily washed from the alum.

Among the cheaper precipitants, are soaper's salt, containing sulphate of potassa, chloride of sodium, &c.; putrefied urine, which is rich in carbonate of ammonia, and the ammoniacal liquor of gas-works. It is an immaterial point for the quality and properties of alum, whether the alkaline base be potassa, ammonia, or a mixture of the two.

After precipitation, the drained alum-meal is washed with a little water, or better with a saturated solution of alum, by stirring it well with the solution, and running off the settled liquid. A second solution of pure alum will remove the last portions of foreign matter adhering to the alum; and this second solution may then be used for the first washing of a new portion of alum-meal.

e. Crystallization. The washed alum is dissolved in a lead pan in a small quantity of water, at a boiling heat; and when saturated, the solution is run off into the crystallizers. These are casks, somewhat tapering below, consisting of staves bound with iron hoops, so arranged that they may be removed, when the solution has fully crystallized. A dense mass of crystals of alum line the sides and bottom, and project from the top of the liquid downward. The hoops and staves are removed; the bottom pierced, to run off the mother liquor; the alum is broken up, and dried for the market. The mother liquors are either further

crystallized alone, or added to the more crude lyes.

Properties of Commercial Alum. We distinguish four kinds of alum, and the sulphate of alumina, which are similarly employed in the arts. These are the potassa and ammoniacal alums; Roman alum, alluded to above; and neutral alum, made by adding some carbonated alkali to common alum. The two former are really neutral; the two latter basic. See *Neutral A.* under *Sulphates of ALUMINA*, and see this article for the properties and composition of these sulphates. They may all contain oxide of iron, some in notable quantity, Roman alum the least, and, therefore, for many purposes the best kind. To ascertain the presence of this oxide, pour a very dilute solution of ferrocyanide of potassium (yellow prussiate of potash) over a solid piece of alum, and if, in the course of 15 to 20 minutes or less time, it exhibit blue spots, it contains too much iron for some delicate colors in dyeing, &c.: the blue which appears after that time, arises from the decomposition of the prussiate. To obtain it very pure, dissolve 2 pts. alum in 3 pts. boiling water, and run it off into 3 pts. of cold water, and stir till cold; the alum-meal which falls is very pure, and by washing and repeating the operation may be obtained absolutely pure.

Potassa and ammonia alums resemble each other in their general properties; the former containing 10.8 and the latter 11.3 per cent. alumina. The Roman and neutral alums are also allied, and contain a larger percentage of alumina; sulphate of alumina still more, = 15.4 per cent. Common alum requires about 12 pts. of water at 60° for solution, basic alums less, and sulphate of alumina only 2 parts.

Uses. Alum is extensively employed in the arts, chiefly in consequence of the affinity of alumina for many coloring and other vegetable matters, for gelatin, &c. Cotton and other fibre has such an attraction for alumina, or a basic salt of it, that when dipped in alum and dried, a basic salt adheres to the cloth, which cannot be removed by washing. It therefore sets free a portion of sulphuric acid, and hence, without due care, cotton may be injured by it. Cotton impregnated with alum and heated in a decoction of madder, quercitron, logwood, &c., takes up a certain portion of the color, which combines with the alumina or its basic salt, and is thus fastened upon the fibre. Such colors being bright, and their corresponding compounds with oxide of iron dark, it is evident that a small percentage of this oxide in alum must diminish the brilliancy of alum colors.

Since the depth of color depends, more or less, on the quantity of alumina which cotton can affix, and since fibre can decompose only a small amount of alum, methods have been devised to obviate this difficulty. Thus, the acetate of alumina, which is easily decomposed by fibre, is made by adding acetate of lead or lime to alum (see *Acetate of Alumina*). The little solubility of alum, only 1 in 12 water, at common temperatures, likewise prevents fibre from decomposing much of the

salt; and hence it is often converted into neutral alum by adding carbonate of soda to neutralize a portion of sulphuric acid. The solution then contains a basic sulphate of alumina, and may be concentrated so as to contain much more alumina in the same bulk of solution. Fibre affixes more alumina from neutral alum, which is therefore used for deep and brilliant colors.

Alum is farther used in the preparation of lakes, which are insoluble precipitates of alumina with vegetable colors; in *tawing* or preparing white skins, from its action on gelatin; for clarifying water, &c., by union with foreign matter in liquids to an insoluble compound; as an addition to paste, by bookbinders, to improve it and prevent the depredations of insects; rarely used to cover or impregnate paper and other combustibles, to render them fire-proof.

ALUM-EARTH. *Geol.* A blackish brown, earthy, sub-slaty mass, constituting subordinate beds in the brown coal formation of Germany, in France, Hungary, &c. It is the brown coal itself, in an impure state, highly charged with clay and pyrites, and therefore well adapted to the manufacture of alum. Klaproth obtained from 1000 pts. alum-earth from Freienalpe, and Bergemann from that of Putzberg—

	Klaproth.	Bergemann.
Coal	196·5	59·5
Sulphur	28·5	39·4
Alumina	160	108
Protoxide of iron	64	55
Protosulphate of iron....	18	57·29
Sulphate of alumina	—	12
Sulphate of lime	15	17·1
Sulphate of potassa	15	17·49
Chloride of potassium ...	5	3·51
Water	107·5	165
Sulphuric acid	—	4·74

Klaproth supposed that the sulphur was combined with iron, but there is no doubt that it exists in it as pyrites. Alum-earth contains a very small amount of alum and other salts

	1.	2.	3.	4.	5.	6.
Silica	24·00	56·5	62·25	28·40		
Sulphuric acid	25	16·5	12·50	27	35·6	35·495
Alumina	43·92	19	17·50	31·80	40·0	39·654
Potassa	3·08	4	1	5·80	13·8	10·021
Water	4	3	5	3·72	10·6	and } 14·830 loss }
Sesquioxide of iron	—	—	—	1·44	—	
	100·00	99·0	98·25	98·16	100·00	100·000

Formula not definitely determined, but the sixth analysis of the crystallized leads rather to the formula $(\text{KO}, \text{SO}_3 + \text{Al}_2\text{O}_3, 3 \text{ SO}_3) + 3 (\text{Al}_2\text{O}_3, 3 \text{ HO})$, which is 1 equiv. anhydrous alum + 3 equiv. hydrate of alumina.

Locality. Formed in lavas and trachytic rocks by the rise of sulphurous vapors. At Tolfá, near Rome; in Beregh, Hungary, where the amorphous rock is so hard as to be employed for mill-stones; in Auvergne, France; on some of the Grecian Islands. See its use in the manufacture of ALUM.

ALLOTROPISM, from *αλλοτροπος*, having dif-

ferent properties. This word is used by Berzelius to designate the different chemical conditions or states in which the same elementary body, as sulphur, phosphorus, carbon, silicon, and perhaps others, may occur. Diamond, graphite and charcoal are thus the different *allotropic* modifications of carbon. Some of them, as phosphorus, have lately been shown by him to retain their allotropic conditions in their combinations with other elementary bodies, as oxygen, hydrogen, nitrogen, and sulphur. See PHOSPHORUS and its combinations. Allotropism is therefore a new source of

ready formed; but by exposure to the air, with or without calcination, sulphate of alumina is produced, as described under ALUM.

ALUM-SLATE. *Geol.* A grayish or bluish black slaty formation, dull, earthy; spec. grav. 2·3 to 2·4; often with petrifications, and generally containing a little bituminous matter, which assists in its calcination for making alum; it always contains pyrites. It is not very abundant, occurring at Whitby and Hurlett, England; in the Netherlands; near Düsseldorf, Prussia; in Sweden, Norway, Saxony, Bohemia, &c. The difference between alum-slate and alum-earth in the manufacture of alum, consists in the invariable calcination of the alum-slate. See ALUM.

ALUM-STONE. *Min. Syn.* Alunite. *Ger.* Alaunstein.

Description. Cryst. hexagonal, an obtuse rhomb of $= 92^\circ 50'$ and $89^\circ 10'$, sometimes with flatter rhombs and terminal plane of main axis; cleavage perfect parallel to this term. plane, less so parallel to planes of rhomb; occurs also crystalline and massive. $H = 5$; $G = 2·6$ to $2·75$; color white, reddish; lustre vitreous, pearly on term. plane; transparent, subtranslucent; brittle; fracture of the massive, splintery; often earthy.

Behavior. In matras gives water, then a minute sublimate of sulphate of ammonia; the crystalline decrepitates violently, falling to a fine powder; shrinks on charcoal without fusion; melts in borax and mic. salt to a colorless glass, leaving silica in the latter; does not fuse with soda, but gives a sulphuret; solution of cobalt gives with it blue. Dissolves in sulphuric acid, in powder; very little in chlorohydric; after gently heating, water dissolves out alum, and it is then nearly all soluble in chlorohydric acid.

Analysis of amorphous, 1. from Tolfá, by Vauquelin, and 2. Klaproth; 3. from Hungary, by Klaproth; 4. from Mont Dore, by Cordier; 5. of a more perfect variety from Montione, by Descotils; and 6. of crystallized, from Tolfá, by Cordier.

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isomerism, since the same number of elementary atoms, even by the same arrangement or position, may form different isomeric compounds, according to their different allotropic conditions. See ISOMERISM.

ALUMINA. *Chem.* The oxide of aluminum, classed among earthy bodies. See under ALUMINUM.

ALUMINITE. *Min.* Syn. Websterite, Halite, Sub- and Tris-sulphate of alumina.

Description. Reniform, botryoidal, massive, earthy. $H = 1.5$, yielding to the nail; $G =$

	1.	2.	3.	4.	5.
Sulphuric acid.....	23.365	23.685	23.370	19.25	21.5
Alumina.....	30.263	30.980	29.868	32.50	31.0
Water.....	46.372	45.335	46.762	47.00	45.0
Other substances.....	—	—	—	1.25	2.0
	100.000	100.000	100.000	100.00	99.5

It is therefore $\frac{1}{3}$ basic sulphate of alumina, and its formula $Al_2O_3, SO_3 + 9HO$, which precisely agrees with the specimen from Newhaven.

Locality. At Newhaven in ferruginous clay; in the same at Epernay, France; and in plastic clay at Halle, Prussia.

ALUMINUM. *Chem.* The metallic basis of the earth alumina. Alum was known to the ancients: Geoffroy proved the presence of alumina in clay; Wöhler first obtained the metal, aluminum. It is the most abundant earthy element, being contained in clays, felspar, and many other silicates.

I. ALUMINUM AND ITS METALLOIDAL COMPOUNDS.

1. *Aluminum.* Equiv. $Al = 13.72$ or 171.17 . Always combines in double equivs.

Prep. Lay some clean pieces of pure potassium on the bottom of a porcelain or platinum crucible, and over them about an equal volume of pieces of dry chloride of aluminum; bind the crucible and cover with wire; heat at first gently with spirit lamp, and increase the heat till a sudden ignition of the crucible indicates complete decomposition. When cold, throw the crucible into a large glass of water; the gray powder of aluminum subsides, which is washed and dried. Liebig puts the chloride of al. in the bent and closed part of a narrow and thin tube, thrusts 2 or 3 small pieces of potassium along the horizontal part of the tube till near the bend, and gently heats the chloride, which, passing in vapor through the potassium, is robbed of its chlorine; more potassium is pushed in until the chlor. of al. is all volatilized; the tube is broken, thrown in cold water, washed with cold water, then with strong alcohol.

Prop. A gray powder similar to powdered platinum, with a few tin-white scales. Rubbed in an agate mortar, it may be easily pressed together into larger scales of a perfectly tin-white lustre, and apparently somewhat malleable. In its powdered state does not conduct electricity. Infusible at the melting heat of cast-iron, excluded from air.

Heated to ignition in the air, it burns with brilliancy to white alumina; heated in oxygen,

1.66 to 1.7. White; opaque, translucent; lustre and fracture earthy; adheres to the tongue, and is meagre to the touch.

Behavior. Heated in matrass, gives much water; when ignited, sulphurous acid; the residue infusible, and behaves like alumina; with soda, forms sulphuret. Easily soluble in chlorohydric acid without effervescence.

Analysis. From Halle, 1; Morl, 2; and Newhaven, 3, by Stromeyer; 4, from Halle, by Simon, and 5, by Bucholz.

burns with a light which the eye can scarcely support, and with such heat as to fuse in part, when it easily cuts glass. In cold and warm water remains untarnished, but heated near to boiling it slowly decomposes it, evolving hydrogen. Dissolves readily in dilute caustic alkali, ammonia, and dilute sulphuric or chlorohydric acids. Not attacked by cold sulphuric or nitric acids, easily when they are heated.

2. *Alumina.* Syn. Oxide of aluminum, Alumine. *Ger.* Thonerde, Alaunerde. Occurs nearly pure in nature in the corundum and ruby; impure, abundant in clays and numerous silicates.

Prep. 1. Precipitate a solution of alum, free from iron, by an excess of carb. soda or potassa, and digest the precip. some time with the same; wash well, dissolve in muriatic acid, filter, precip. by ammonia, and ignite the precipitate, which is hydrate of alumina. (*Berzelius.*) 2. Precipitate an alum-solution by an excess of chloride of barium, evaporate to dryness, ignite the remainder, and extract chlorides of barium and potassium by water, acidulated with chlorohydric acid. (*Liebig.*) 3. Ignite pure ammoniacal alum.

Prop. The properties of native and precipitated alumina necessarily vary. For the former see CORUNDUM. As above prepared, it is a white powder, light and loose when gently ignited, but denser and giving sparks with steel after strong ignition. In the latter case, its spec. grav. = 4.152. Native and precip. alumina fuse by the oxyhydrogen blowpipe more easily than silica. Gaudin fused the precip. alumina to a bead of a hazelnut size, with a cavity containing crystals of corundum. That fused by igniting aluminum in oxygen is yellowish. Alumina is odorless and tasteless, wholly insoluble in water, although it has a strong affinity for it, forming 2 hydrates. Ignited dry alumina attracts moisture from the air powerfully, which may amount to 15 per cent.

Hydrates. A tribasic hydrate of al. is found as DIASPORE = Al_2O_3 , aq. Another hydrate is GIBBSITE = Al_2O_3 , 3 aq., which is the same as precipitated al. The latter hydrate is prepared by precipitating chloride of aluminum by an excess of ammonia, and washing the precip. well with hot water. Thus made, it is either

white, opaque, pulverulent, or cohering, translucent, adhesive to the tongue. It loses its water by ignition, and shrinks to a small bulk.

Combinations. The hydrated al. dissolves readily even in dilute acids; the ignited does not, but by digestion with strong chlorohydric, or when heated with sulphuric, with an equal weight of water, it becomes soluble. It is readily soluble in caustic alkalies, to a very small amount in ammonia, much more in barytic or strontian waters. It is, in general, a feeble base, and with alkalies, and some other metallic oxides, seems to act as an acid, as with magnesia and oxides of zinc and iron in the minerals gahnite and spinell. Such combinations are sometimes termed *aluminates*.

Tests. Al. is usually separated from oxide of iron by solution in caustic potassa, and after neutralization is precip. by carb. ammonia. When alone or in many minerals, it is recognised by the blowpipe by a drop of a solution of nitrate of cobalt, which, when strongly ignited with it, appears when cold of a blue color.

Uses. Al. is employed in the arts from the affinity of the earth or its basic salts both for fibre and most organic colors, producing beautifully colored compounds, insoluble in water. See *ACETATE of Alumina* and *DYEING*. Mingled with silica, as in clays, it is also the basis of bricks, pottery and porcelain.

	H = 1	O = 100.	In 100 pts.
2 Al	27.4	342.33	53.3
3 O	24	300.00	46.7
Al ₂ O ₃	51.4	642.33	100.0

3. *Sulphuret of Aluminum.* Formed by throwing sulphur on ignited aluminum, when they unite, evolving light and heat; but sulphur may be distilled off from the metal without combination. It is a black, semifused mass, of sub-metallic lustre, tasting and smelling of sulphuretted hydrogen, which it gradually gives off, falling to a gray powder in the air, but rapidly changing in water into the same gas and gray alumina. Form., Al₂S₃. A very feeble sulpho-base.

4. *Phosphuret of Al.* The metal heated to ignition in vapor of phosphorus or in phosphuretted hydrogen, combines with P. with a lively combustion, forming a blackish gray, pulverulent mass, which exhibits a dark-gray color and metallic lustre by friction, smells of phosphur. hydrogen, and evolves the same non-inflammable gas slowly in cold, rapidly in hot water.

5. *Seleniuret of Al.* Selenium and al., by fusion together, unite with combustion to a black pulverulent mass, dark metallic by friction, which evolves selenuretted hydrogen slowly in the air, rapidly in water; the water appears red from the precip. of selenium.

6. *Telluret of Al.* By fusing tellurium and al. together, the union is so rapid that when in a powdered state they are violently ejected from the vessel. It is a black, semifused, metallic, brittle mass, smells of telluretted hydrogen, evolves the same rapidly in water.

ALLOYS. *Arsenic* and *Al.* unite with combustion, by heating them to ignition; it is dark gray,

pulverulent, metallic by friction; evolves arseniuretted hydrogen very slowly in air, slowly in cold, rapidly in warm water.

Iron and *al.* unite, for we generally find traces of al. in cast-iron, alumina in the ore having been reduced by the imparted affinity of the iron.

II. SALTS.

Aluminous salts are colorless with a colorless acid, generally soluble, and often crystallizable, the basic often insoluble. They are decomposed by ignition, leaving alumina, if the acid be volatile. They have an acidulate, astringent, and sweetish taste, and reddened litmus. Strongly ignited with a little nitrate of cobalt, they give a beautiful blue color, unless some other oxides be present. The alkalies precipitate hydrate of alumina, but an excess of potassa or soda redissolves it; sal-ammoniac added to the last again precipitates alumina; ammonia redissolves very little. Neutral and bicarbonates and sulpho-hydrates of ammonia, soda, or potassa, and even carb. lime precip. hydrate of alumina, evolving carbonic or sulpho-hydric acid; dilute solutions in excess redissolve a mere trace. Concentrated solutions of aluminous salts mixed with sulphuric acid in excess, and ammonia or potassa, yield a precip. of alum-crystals. Ferrocyanide of potassium precip. slowly in the cold, rapidly by heating, hydrate of alumina, evolving prussic acid; if iron be present, the alumina is greenish or bluish. Tincture of galls throws down yellow flocculæ. Al. salts are not precip. by sulphuretted hydrogen, fluosilicic or oxalic acids, oxalated or tartarated alkalies.

There being 3 eq. oxygen in alumina, its neutral salts contain 3 eq. acid; their formula is therefore Al₂O₃ + 3R_mO_n. It has, however, a tendency to form basic salts, few of which have been investigated; their formula is probably Al₂O₃ + 2R_mO_n or R_mO_n.

HALOID SALTS.

A. Chlorine. 1. Chloride of Aluminum, Dry.—

Prep. Chlorine passed over ignited aluminum, unites with combustion to the chloride, which sublimes. Pass dry chlorine over a mixture of charcoal and alumina in an ignited porcelain tube. The latter process of Oersted is thus executed by Liebig. Add to a pure alum solution an excess of chloride of barium; evap. the filtrate to a syrupy consistence, and let the chlorides of barium and potassium crystallize out; evap. the decanted liquid to dryness, mixing it with $\frac{1}{3}$ sugar or starch, and strongly ignite in a covered crucible, which gives an intimate mixture of pure alumina and charcoal; put it into a green glass tube, 2 to 2½ ft. long, $\frac{1}{2}$ inch diameter; connect one end with one opening of a balloon, in the other opening of which is a narrow glass tube thrust through a cork to allow of the escape of carbonic oxide. Chlorine enters the other end of the ignition-tube. Liebig dries his chlorine by passing it through a Woulfe's bottle containing concent. sulphuric acid, which allows the rapidity of the operation to be observed. When the whole apparatus is filled with chlorine, the tube is heated to ignition, and the balloon attached as

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soon as moisture ceases to appear. Most of the chloride of aluminum collects at the end of the tube in dark yellow drops, which congeal, the rest as a loose powder in the balloon. That in the tube is drawn out by a strong wire, and with the powder is distilled in a retort, in the neck of which the pure salt collects.

Prop. Citron-yellow, translucent, of waxy lustre, talcose crystalline texture; fusible in larger masses, in smaller instantly volatilizing; boils at 356° to 365° ; fumes slightly in the air, smelling of chlorohydric acid; very soluble in alcohol. Decomposed by potassium. (See *Prep. of Aluminum*.) When distilled with dry sulphuric acid, sulphurous acid and chlorine pass off and leave sulphate of alumina. (*H. Rose.*) $\text{Al}_2\text{Cl}_3 + 6\text{SO}_3 = \text{Al}_2\text{O}_3 + 3\text{SO}_2 + 3\text{SO}_3 + 3\text{Cl}$.

Composition.	H=1	O=100	In 100 pts.
2 Al	27.4	242.33	20.46
3 Cl	106.5	1331.25	79.54
Al_2Cl_3	133.9	1573.58	100.00

It appears to combine with other chlorides, as an electro-negative body; and the compounds thus formed may be termed double chlorides, or chloro-aluminates, or aluminochlorides.

Hydrated Chloride of Al. The dry chloride deliquesces in the air, dissolves rapidly in water with the evolution of heat. It is prepared by precip. sulphate of alumina by chloride of barium, or by dissolving hydrous alumina in chlorohydric acid. The solution evaporates spontaneously in a warm room and dry air, yielding crystals of the hexagonal system, usually the 6-sided prism, with rhombic terminations, with angles of 138° ; as ordinarily formed, it is a deliquescent saline mass. The crystals very soluble in water and alcohol, very deliquescent, when heated lose, without fusion, both water and chlorohydric acid, leaving alumina in the form of the crystals. *Bonsdorff.*

2. *Oxychloride of Aluminum.* By adding an insufficient quantity of ammonia to a solution of chloride of aluminum, this compound precip., and by washing on the filter becomes translucent; is slightly soluble in water. *Berz.*

Comp. of the cryst.	H=1	O=100	In 100 pts.
2 Al	27.4	242.33	11.32
3 Cl	106.5	1331.25	44.02
12 HO	108.0	1230.00	44.66
	241.9	2803.58	100.00

3. *Chloride of Al. and Sulpho-hydric Acid.* When chloride of al. is sublimed in a rapid stream of dry sulphuretted hydrogen, this compound sublimes in the neck of the retort, partly as clear, pearly laminae, partly as a fused, white, brittle mass. Sublimed in a glass tube, it loses part of its sulphuretted hydrogen; in air it is deliquescent, evolving sulph. hydrogen; evolves the same rapidly in water, leaving a solution of chloride of al., clouded with sulphur. *Wöhler.*

4. *Chloride of Al. and Phosphuretted Hydrogen.* Chlor. of al. slowly absorbs phosphur. hydrogen in the cold; when heated in a stream of it

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nearly to sublimation, they unite, and the compound sublimes in crystals. It evolves in water phosphuretted hydrogen, not self-inflammable; ammonia evolves the self-inflammable only. Form., $3(\text{Al}_2\text{Cl}_3) + \text{PH}_3$.

5. *Chloride of Al. and Ammonia.* Chloride of al. absorbs dry ammonia slowly at first, then suddenly in such quantity that the compound is fused by the heat evolved. By distilling this compound, another passes over, and by distill. in an atmosphere of hydrogen, a third compound is produced. *Rose, Persoz.*

The 1st is $3\text{NH}_3 + \text{Al}_2\text{Cl}_3$; the 2d $\text{NH}_3 + \text{Al}_2\text{Cl}_3$; the 3d doubtful.

6. *Alumino-Chloride of Potassium.* In the prep. of chloride of al. by alumina and charcoal, if the former contain potassa, pure chloride of al. first passes over; subsequently there are deposited, near the mixture in the tube, colorless drops, which congeal to a white, translucent, crystalline mass. Deliquescent in air, very soluble in water, leaves by ignition 64.48 per cent. of a mixture of 26.67 alumina and 37.81 chloride of potassium. *Degen.* It is probably $\text{KCl} + \text{Al}_2\text{Cl}_3$.

7. *Alumino-Chloride of Sodium.* Chloride of sodium heated in chloride of al. unites with it to a yellow compound, which may be heated to strong ignition without losing chloride of al.; is soluble in water, evolving heat, and then by evap. yields chloride of sodium.

B. *Bromine.* Dry Bromide of Aluminum is formed similarly to the chloride. The hydrated, formed by solution of hydrate of alumina in bromohydric acid, separates from a concent. solution in groups of fine, short needles, very deliquescent, very soluble in alcohol and water, of a stypitic taste and acid reaction. *Löwig, Berthelot.*

C. *Fluorine.* 1. *Fluoride of Aluminum.* Unknown in a dry state. The hydrated made by dissolving hydrate of alumina in fluohydric acid, evaporating to a syrup, drying to a yellowish, translucent, fissured, gum-like mass; easily removable from the vessel. Tasteless, at first insoluble, afterwards wholly soluble in water; the solution attacks glass. Form. Al_2F_3 . It is contained in *PRECIPE*, combined with silicate of alumina. *Berz.*

2. *Oxyfluoride of Al.* Formed by ignition of the preceding, with loss of fluohydric acid; the hydrated by digesting the solution of 1. with alumina, forms a semitranslucent jelly, drying to a yellowish gummy mass. This oxyfluoride is combined with silicate of alumina in *TOPAZ*. *Berz.*

3. *Alumino-fluoride of Potassium.* a. Drop a solution of fluoride of al. into a solution of fluoride of potassium, the latter being still in excess; the gelatinous precip. after washing and drying is white and powdery. Form., $3\text{KF} + \text{Al}_2\text{F}_3$. *Berz.*

b. By adding fluoride of potassium to fluoride of al. with the latter in excess, the precip. appears similar to the preceding, but its formula is $2\text{KF} + \text{Al}_2\text{F}_3$. By digesting hydrate of alumina with bifluoride of potassium, the first portions of alumina are dissolved, but by adding more, the double fluoride b is precip.; $3\text{KF}, 3\text{HF} + \text{Al}_2\text{O}_3 = 2\text{KF}, \text{Al}_2\text{F}_3 + \text{KF} + 3\text{HO}$; while neutral fluoride of potassium re-

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mains in solution. If this precip. be boiled with the supernatant liquid, the equiv. of KF is again taken up, and the double fluoride *a* is produced; $2\text{KF}, \text{Al}_2\text{F}_3 + \text{KF} = 3\text{KF}, \text{Al}_2\text{F}_3$. When the hydrate of alumina is in excess and the liquid is boiled to concentration, an aluminofluoride is produced with such force that the liquid contains free potassa.

Both *a* and *b* are gelatinous, drying to white powders, difficultly soluble in dilute acids, with more difficulty in water; evolve fluohydric acid, when heated with a mixture of equal parts sulphuric acid and water; and when thus fully decomposed, ammonia precip. pure alumina.

4. *Alumino-fluoride of Sodium.* Add hydrate of alumina to bifluoride of sodium portionwise, until acid reaction ceases; gelatinous, drying to a white powder, less soluble than the same compound of potassium, by long-continued fusion in the air loses fluohydric acid and its fusibility, becoming probably an oxyfluoride; heated with sulphuric acid, loses fluohydric acid. By digesting neutral fluoride of sodium with hydrate of alumina, it is more easily rendered caustic than the salt of potassium. Form. $3\text{NaF}, \text{Al}_2\text{F}_3$. The same compound is found native, the *CROOLITE*, which see.

5. *Alumino-fluoride of Lithium.* A similar insoluble salt.

6. *Alumino-fluoride of Ammonium.* By digesting hydrous alumina with fluoride of ammonium, some ammonia is evolved, and the double salt remains; gelatinous, translucent, drying to a white powder, not soluble in either of its constituents, somewhat soluble in water, from which it is precip. by ammonia; heated, it evolves ammonia, then bifluoride of ammonium, and leaves a basic fluoride of aluminum. *Berz.*

7. *Borofluoride of Al.* Crystallizes from an acid solution by slow evaporation. When borofluoride of sodium is mixed with chloride of al., a basic compound precip., the liquid contains free acid, which holds a portion of the precip. in solution. The precip. fuses by ignition, evolves fluoboric acid and water, leaving fused borate of alumina.

8. *Silicofluoride of Aluminum.* Very soluble in water; by evaporation yields a clear, colorless jelly, becoming yellowish and translucent by drying; it is then slowly but perfectly soluble in water. *Berz.*

OXY-SALTS.

1. *Sulphate of Alumina.* *a. Neutral.* Formed by dissolving hydrous alumina or calcined clay in dilute sulphuric acid (see under *ALUM*); is found native and cryst., see *ALUNOGEN*. Cryst. artificially in thin, flexible, pearly leaves and needles, from a solution in chlorohydric acid in beautiful tables.

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Prop. It has a sweetish, styptic taste; soluble in 2 pts. cold water, scarcely in alcohol; heated, it fuses in its crystal-water, and loses it, puffing up, leaving the dry, spongy salt; at ignition loses its acid. It contains 48.59 per cent. = 18 eq. water. Form. $\text{Al}_2\text{O}_3, 3\text{SO}_3 + 18\text{aq.}$ *Berz.* See its uses under *ALUM*.

b. $\frac{1}{3}$ basic Sulphate of Al. Formed by digesting *a* with hydrous alumina or carbonate of lime; or by warming for some time a concentrated solution of *a* with *c*, filtering hot and evap. gently to dryness. A gummy mass, becoming opaque in the air and decomposing by much water into *a* in solution, while *c* precipitates. Form. $\text{Al}_2\text{O}_3, 2\text{SO}_3$. The water not ascertained.

c. $\frac{2}{3}$ basic Sulphate of Al. Formed by precip. *a* with ammonia. When dry, a white powder, insoluble in water. Found native in *ALUMINITE*. Form. $\text{Al}_2\text{O}_3, \text{SO}_3 + 9\text{aq.}$

d. $\frac{5}{6}$ basic Sulphate of Al. Rammelsberg observed a crystalline deposit on the sides of a glass, after several years' standing, containing dilute sulphuric acid fully saturated with alumina; under the microscope they appear as small transparent needles; lose water at a gentle heat, acid by ignition; very soluble in nitric or chlorohydric acids, in 144 cold and 30.8 boiling water. Form. $3\text{Al}_2\text{O}_3, 4\text{SO}_3 + 30\text{aq.}$

e. The mineral *PISSOPHANE*, according to Erdman, is composed of $5\text{Al}_2\text{O}_3, 2\text{SO}_3 + 30\text{aq.}$

2. *Sulphate of Alumina and Potassa.* *a. Neutral.* See *ALUM* for its manufacture, synonyms, &c. It crystallizes in the regular system, usually an octahedron, combined with the cube and 12-hedron, its edges and pyramids being replaced by planes; it is sometimes in the form of the cube, the 4 × 6-planer, and the 24-planer.

Translucent, colorless; fracture conchoidal; taste acidulate, sweetish astringent; reddens litmus; spec. grav. 1.724.

It is soluble in 13.3 pts. water at 56°, in 8.2 at 70°, in 4.5 at 77°, in 2.2 at 100°, in 2 at 122°, in 0.4 at 145°, in 0.1 at 167°, in 0.06 at 190°; spec. grav. of the saturated solut. at 46° = 1.045. Almost insoluble in neutral sulphate of alumina. It loses at 142° 18 eq. water; when slowly heated to a point below ignition it loses its water with much puffing and foaming, and becomes *dried* or *burned alum*, a loose, friable mass, which is at first insoluble in water, but gradually dissolves. At a white heat, burned alum loses the sulphuric acid of the alumina, partly as such and partly as sulphurous acid and oxygen, while alumina and sulphate of potassa remain. Ignited with charcoal it forms Hornberg's *Pyrophorus*. Cryst. alum heated with chloride of potassium, evolves chlorohydric acid; its concentrated solution, boiled with the same salt, gives off the same acid, and deposits a basic alum of difficult solubility.

Cryst.	H = 1	O = 100	In 100 pts.	Thomson.	Graham.
KO	47.2	589.9	9.95	9.86	54.11
Al_2O_3	51.4	642.3	10.83	11.09	
4SO_3	160.0	2004.6	33.71	32.85	
24HO	216.0	2700.0	45.51	46.20	
Potassa alum	474.6	5936.8	100.00	100.00	100.00

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Formula, $\text{KO}, \text{SO}_3 + \text{Al}_2\text{O}_3, 3\text{SO}_3 + 24\text{HO}$; $(\text{KO}, \text{SO}_3 + 6\text{HO}) + (\text{Al}_2\text{O}_3, 3\text{SO}_3 + 18\text{HO})$
Kane; $\text{KO}, \text{SO}_3 + (\text{Al}_2\text{O}_3, 3\text{SO}_3 + 6\text{aq.} + 18\text{aq.})$ *Graham*.

b. $\frac{1}{3}$ Basic Sulphate of *Al.* and Sulph. of Potassa. Syn. Basic or cubical alum. *Ger.* Neutral oder kubischer Alaun. Frequently prepared for dyeing and calico-printing, by adding potash to a solution of common alum as long as the precipitate redissolves by agitation; or boil 12 alum and 1 slacked lime in water. By evaporation it crystallizes in cubes. Taste sweetish, styptic; has not an acid reaction; fuses by heat in its crystal-water, puffs up and becomes a porous white mass. Probable formula, $\text{KO}, \text{SO}_3 + \text{Al}_2\text{O}_3, 2\text{SO}_3$.

Uses. The solution of this salt, or rather a mixed solution containing this salt, is largely employed in dyeing, &c., for which purposes it has manifest advantages over common alum, since the latter by its acid reaction is apt to change the tone of colors, and because the acetic alum base (red liquor) prepared from cubical alum is richer in alumina; as a mor-

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dant it is also more easily decomposed than common alum. In adding potash, soda, or ammonia, an excess is apt to produce an insoluble, more basic alum, *c*, which would be a loss in dyeing and printing operations.

c. A still more basic alum may be made by precip. alum-solution by a quantity of potassa insufficient to combine with all the acid of the alumina; or by boiling alum-solution with hydrate of alumina. A white, tasteless powder, insoluble in water, soluble in acids, and then forming common alum. By gently heating, water is expelled, part of the alumina is rendered insoluble, and water then dissolves out common or $\frac{1}{3}$ basic alum. This alum is found native; see ALUM-STONE. Probable formula, $\text{KO}, \text{SO}_3 + 3(\text{Al}_2\text{O}_3, \text{SO}_3) + 9\text{aq.}$

3. Ammonia-Alum. See ALUM manufacture. Resembles the preceding, *a*, closely in nearly all its external characters, crystalline form, taste, fracture, &c.; spec. grav. 1.626.

Its solubility is similar to that of potassa-alum, which it also resembles in a gentle heat, but when strongly heated leaves pure alumina.

Cryst.	H = 1	O = 100	In 100 pts.	Riffault.	Forchhammer.
NH_3	17	214.5	3.75		
Al_2O_3	51.4	642.3	11.34	11.906	11.24
4SO_3	160	2004.6	35.29	36.042	35.90
25HO	225	2812.5	49.62	—	—
	453.4	5673.9	100.00	—	—

Formula, $\text{NH}_4\text{O}, \text{SO}_3 + \text{Al}_2\text{O}_3, 3\text{SO}_3 + 24\text{aq.}$; or, $(\text{HO}, \text{SO}_3\text{HAd} + 6\text{aq.}) + (\text{Al}_2\text{O}_3, 3\text{SO}_3 + 18\text{aq.})$.

b and *c.* Basic Ammonia-Alums. Formed similarly to the corresponding potassa-alums, by adding ammonia to ammonia-alum. Properties similar, except that *b* has not been well crystallized. Formula for *b* is probably $\text{NH}_4\text{O}, \text{SO}_3 + \text{Al}_2\text{O}_3, 2\text{SO}_3$, + and for *c*, $\text{NH}_4\text{O}, \text{SO}_3 + 3(\text{Al}_2\text{O}_3, \text{SO}_3) + 9\text{aq.}$

4. Sulphate of Al. and Soda. Syn. Soda-alum. Found native, see ALUM. *Min.* Made by suffering the mixed solutions of sulphates of soda and alumina to evaporate spontaneously. Cryst. octahedron, similar to potassa-alum, brittle, spec. grav. 1.6. The crystals effloresce in dry air, falling to a white flour; insoluble in absolute alcohol; soluble in 2.14 pts. water at 55.4°, in 1 pt. boiling; the latter solution congeals to a soft crystalline mass.

	H = 1	O = 100	In 100 pts.	Wellner.	Zellner.	Graham.
NaO	31.3	290.9	6.80	6.29	6.67	52.53
Al_2O_3	51.4	642.3	11.21	10.19	11.00	
4SO_3	160	2004.6	34.89	35.10	34.32	
24HO	216.0	2700.0	47.10	48.22	48.01	47.47
	458.7	5637.8	100.00	99.80	100.00	100.00

5. Sulphate of Al. and Lithia. Syn. Lithia-alum. A mixed solution of the two sulphates, evap. below 52°, yields the salt in octahedra and 12-hedra; soluble in 24 cold, in 0.87 hot water. Form., $\text{LO}, \text{SO}_3 + \text{Al}_2\text{O}_3, 3\text{SO}_3 + 24\text{HO}$. Kralovszky found 50.61 per cent. water: by the form. there should be 48.89 per cent.

6. Sulphate of Al. and Magnesia. *a.* Syn. Magnesia-alum. Occurs native, see ALUM. *Min.* There are 49.3 per cent., or 25 eq. water in this salt, and Kane gives the formula, $\text{MgO}, \text{HO}, \text{SO}_3 + \text{Al}_2\text{O}_3, 3\text{SO}_3 + 24\text{HO}$, regarding MgO, HO as isomorphic with KO.

b. Another compound is obtained in fine needles, from a very acid solution of sulphates of magnesia and alumina in a rough-surfaced porcelain cup. (*Klawer*.) According to his analysis its formula is $3(\text{MgO}, \text{SO}_3) + \text{Al}_2\text{O}_3$,

$3\text{SO}_3 + 36\text{aq.}$ More probably magnesia-alum, = $\text{MgO}, \text{SO}_3 + \text{Al}_2\text{O}_3, 3\text{SO}_3 + 24\text{aq.}$, with 2 eq. sulphate of magnesia = $2(\text{MgO}, \text{SO}_3 + 6\text{aq.})$

7. Sulphate of Al. and protoxide of Iron. Syn. Ferrous alum. Formed by mixing copperas and neutral sulphate of alumina, in solution, with sulphuric acid. Spontaneous evap. produces long acicular crystals, with the formula, $\text{FeO}, \text{SO}_3 + \text{Al}_2\text{O}_3, 3\text{SO}_3 + 24\text{aq.}$ The crystallization not being in the regular system, it can be regarded as an alum only in reference to atomic composition.

8. Sulph. of Al. and protox. of Manganese. Syn. Manganous alum. A compound similar to the preceding has been found native. See both under ALUM. *Min.*

9. Hyposulphate of Alumina. Precipitate neu-

tral sulphate of alumina by hyposulphate of baryta, and filter; by spontan. evaporation small crystals are formed; easily decomposed and difficult to crystallize.

10. *Sulphite of Alumina*. *a*. Neutral (?). Pass sulphurous acid through freshly precipitated hydrate of alumina. A clear solution, which, by evap. in vacuo, leaves a gummy mass; oxidizes in the air to sulphate; heated to 165° gives off much sulphurous acid, *b*. precip., and sulphurous acid, but no alumina remains in the liquid. *Gougginsperg, An. der Chem.* xlv. 132.

b. Obtained by heating solution of *a*. to 165°. A white powder, of sulphurous taste, evolves sulphurous acid at 212°, and by continued ignition leaves pure alumina; soluble in sulphurous acid, not in water; oxidizes to sulphate of alumina. Comp. by analysis, alumina 43.10, sulphurous acid 27.04, water 29.86 = 100, corresponding to the formula $\text{Al}_2\text{O}_3, \text{SO}_2 + 4 \text{ aq.}$ *Gougg.* as above.

Nitrate of Alumina. Saturate nitric acid with hydrate of alumina, evaporate to a syrup; crystallizes in thin radiated laminæ, by a rapid evap. forms a gummy mass. Taste acid, styptic, has acid reaction; very soluble in alcohol and water, deliquescent; easily decomposed by heat. Form., $\text{Al}_2\text{O}_3 + \text{NO}_5$, containing 24 per cent. alumina + 76 acid. Ammonia throws down a pasty precip., a basic salt, which is not robbed of acid by an excess of ammonia. *Berz.*

1. *Phosphate of Alumina*. *a*. Neutral. Add phosphate of soda to a solution of alum; a gelatinous precip., drying to a white and tasteless powder, which is insoluble in water, soluble in acids and caustic potassa; fuses by heat to a white enamel. Form., $2 \text{ Al}_2\text{O}_3 + 3 \text{ PO}_5$. The acid phosphate, made by dissolving *a*. or other phosphates in aqueous phosphoric acid, by evaporation, yields a gummy mass, which is deliquescent, and fuses by heat to a transparent glass. *Pyrophosphate of Al.* is insoluble in acetic acid.

b. $\frac{1}{2}$ Basic phosphate of Al. Formed by precipitating an acid solution of *a*. by an excess of ammonia. A white, subtranslucent precip., soluble in potassa and reprecipitated by salamoniac or acids. Form., $4 \text{ Al}_2\text{O}_3 + 3 \text{ PO}_5$. *WAVELLITE* consists chiefly of this salt.

c. $\frac{2}{3}$ Basic phosphate of Al. Apparently the *TURQUOISE*. Doubtful.

It is somewhat difficult to separate phosphoric acid and alumina. Add to a solution of phosphate of al. in chlorohydric acid, tar-

taric acid, then ammonia, and lastly chloride of magnesium, as long as the phosphate of ammonia and magnesia precip. *Otto.*

2. *Phosphate of Al. and Lithia*. Precip. a saturated solution of phosphate of al. in potassa by a salt of lithia. Occurs native in *AMBYGONITE*. (*Berz.*) Form., $2 \text{ LO}, \text{PO}_5 + 4 \text{ Al}_2\text{O}_3, 3 \text{ PO}_5$.

3. *Phosphate of Al. and Magnesia*. Occurs in the mineral *LAZULITE*.

4. *Phosphite of Alumina*. To a solution of alum add a solution terchloride of phosphorus, saturated by ammonia. The precip. at first disappears, then remains; by boiling a new quantity precip.; a white powder, little soluble in water; heated in a retort yields hydrogen and vapor of phosphorus, with a white residue. *Rose.* Form., $2 \text{ Al}_2\text{O}_3 + 3 \text{ PO}_3$.

5. *Hypophosphite of Alumina*. Hypophorous acid saturated with hydrous alumina in the cold, and evap. in vacuo, leaves a thick paste, which dries in cold dry air to a gum-like, shining, brittle mass, not deliquescent; heated in a retort, yields first self-inflammable, then non-self-infl. phosphuretted hydrogen, with a reddish residue. *Rose.*

1. *Perchlorate of Alumina*. Hydrous alumina dissolved in perchloric acid, dries to a gummy, deliquescent mass, with acid reaction, soluble in water and alcohol. *Serullas.*

2. *Chlorate of Alumina*. Precip. a solution of silico-fluoride of aluminum by a saturated boiling solution of chlorate of potassa, filter and evaporate. Deliquescent, deflagrates on ignited coal with violet flame. *Berz.*

1. *Carbonate of Alumina*. Alumina has a very feeble attraction for carbonic acid, and this salt exists only a short time in solution.

2. *Double carbonates* with alkalies, are rather more permanent. When aluminous solutions are precip. by an excess of carbonated alkali, the precip. always contains carbonic acid, alkali, and alumina.

Borate of Alumina. Precip. alum-solution by borax; white, pearly scales, very slightly soluble in water. With excess of acid, deliquescent, styptic, fusing to a clear glass.

Silicates of Alumina. There are a few simple and numerous double silicates of alumina in the mineral kingdom, and among the products of art. The following general view embraces a large number of them, the details of which will be presented under separate articles.

A.—SIMPLE SILICATES.

- | | | | |
|--|-------------------|---|---|
| 1. Neutral silicate of alumina. | <i>Cimolite</i> | = $\text{Al}_2\text{O}_3, 3 \text{ SiO}_3 + 3 \text{ aq.}$ | |
| 2. $\frac{2}{3}$ ditto. | ditto. | <i>Razoumoffskin</i> | = $\text{Al}_2\text{O}_3, 2 \text{ SiO}_3 + 3 \text{ aq.}$ |
| 3. ditto. | ditto. | <i>Bole</i> | = $\text{Al}_2\text{O}_3, 2 \text{ SiO}_3 + 6 \text{ aq.}$ See also CLAY. |
| 4. $\frac{1}{3}$ ditto. | ditto. | <i>Kaolin</i> | = $2(\text{Al}_2\text{O}_3, \text{SiO}_3) + 3 \text{ aq.}$ |
| 5. ditto. | ditto. | <i>Pholerite</i> | = $\text{Al}_2\text{O}_3, \text{SiO}_3 + 2 \text{ aq.}$ |
| 6. $\frac{1}{6}$ ditto. | ditto. | <i>Kollyrite</i> | = $3 \text{ Al}_2\text{O}_3, \text{SiO}_3 + 15 \text{ aq.}$ |
| 7. Neutral silic. and hydrate of alumina. | <i>Halloysite</i> | = $\text{Al}_2\text{O}_3, 3 \text{ SiO}_3 + \text{Al}_2\text{O}_3, 3 \text{ aq.}$ | <i>Berthier.</i> |
| | ditto. | = $2(\text{AlO}_3, 2 \text{ SiO}_3) + \text{Al}_2\text{O}_3, 2 \text{ aq.}$ | <i>Boussingault.</i> |
| 8. $\frac{1}{3}$ silicate of al., anhydrous. | <i>Bucholzite</i> | = $\text{Al}_2\text{O}_3, \text{SiO}_3$ | |
| 9. $\frac{1}{2}$ ditto. | ditto. | <i>Andalusite</i> | = $4 \text{ Al}_2\text{O}_3, 3 \text{ SiO}_3$ |
| 10. $\frac{1}{6}$ ditto. | ditto. | <i>Kyanite</i> | = $2 \text{ Al}_2\text{O}_3, \text{SiO}_3$ or $3 \text{ Al}_2\text{O}_3, 2 \text{ SiO}_3$. |

B.—DOUBLE SILICATES.

1. Neutral silicate of al. and alkali. *Felspar* and *Albite* = $\text{RO}, \text{SiO}_3 + \text{Al}_2\text{O}_3, 3 \text{SiO}_3$, the RO expressing potassa or soda.
2. Persilicate of al., lithia and soda.

$$\begin{array}{l} \text{Petalite and} \\ \text{Spodumen,} \end{array} \left\{ \begin{array}{l} 3 \text{RO}, 4 \text{SiO}_3 + 4 (\text{Al}_2\text{O}_3, \frac{4}{2} \text{SiO}_3). \end{array} \right.$$
3. $\frac{2}{3}$ silic. of al. + neutral silic. of soda. *Soda-spodumen* = $\text{NaO}, \text{SiO}_3 + \text{Al}_2\text{O}_3, 2 \text{SiO}_3$.
4. $\frac{2}{3}$ silic. of al. and potassa. *Leucite* = $3 \text{KO}, 2 \text{SiO}_3 + 3 (\text{Al}_2\text{O}_3, 2 \text{SiO}_3)$.
See also *Labrador*, *Scapolite*, *Sodalite*, &c.
5. The *Micas* belong likewise to double silicates, but some of their formulæ are too complex to be introduced here. Refer to them.
6. The *Zeolites* are hydrous silicates of al. and alkalies or alkaline earths, such as *Analeime*, a $\frac{2}{3}$ silicate of al. and soda = $3 \text{Na}, 2 \text{SiO}_3 + 3 (\text{Al}_2\text{O}_3, 2 \text{SiO}_3) + 6 \text{aq.}$, and *Stilbite*, a neutral silic. of al. and lime = $\text{CaO}, \text{SiO}_3 + \text{Al}_2\text{O}_3, 3 \text{SiO}_3 + 6 \text{aq.}$
See also *Chabasie*, *Mesotype*, *Heulandite*, *Laumonite*, &c.
7. $\frac{1}{3}$ silicate of al. and a protoxide = $3 \text{RO}, \text{SiO}_3 + 2 (\text{Al}_2\text{O}_3, \text{SiO}_3)$ in which the RO is lime, magnesia, protoxides of iron or manganese, and the alumina is sometimes replaced by sesquioxide of iron. *Garnet*.
8. $\frac{1}{3}$ silicate of al. and a protoxide = $3 \text{RO}, \text{SiO}_3 + \text{Al}_2\text{O}_3, \text{SiO}_3$, in the same bases RO occur as in the preceding, and Al_2O_3 may be Fe_2O_3 .
See also *Idocrase*, *Gehlenite*, *Dichroite*, &c.
9. There are some minerals in which alumina appears to act the part of an acid, such as *Staurolite*, which may be viewed as silicate of alumina and aluminate of sesquioxide of iron, = $3 (\text{Al}_2\text{O}_3, \text{SiO}_3) + \text{Fe}_2\text{O}_3, 2 \text{Al}_2\text{O}_3$.

The above shows the varying proportions in which silica and alumina unite, from which we might infer, what is in truth the fact, that artificial silicates of alumina must also vary materially in composition. All the varieties of the clay-manufactures and many slags or cinders in furnace operations are double silicates of alumina, and alkalies or alkaline earths. Now, of the simple silicates of alumina, none are known to fuse in the highest temperatures of our furnaces, but the neutral or $\frac{2}{3}$ silicate of al. when exposed to a very intense heat softens, so that it bends, and when cold agglomerates, becoming somewhat hard and stony. When an alkali or alkaline earth is added, even in small quantity, it renders the mass more fusible by the formation of double silicates. Of such a composition are most of the clays employed in the making of brick or common earthenware, while kaolin and some other clays, being nearly pure and infusible, require the addition of a little alkaline matter, such as felspar and lime, for the manufacture of porcelain and the finer kinds of pottery. See farther under **POTTERY, IRON, &c.**

For the compounds of alumina with the acids of Selenium, Tellurium, Arsenic, and other metals, see those metals. For the uses of the salts of alumina in dyeing operations, consult **ACETATE** of alumina, **ALUM**, and **DYEING**.

ALUMOCALCITE. *Min.* Massive; may be crushed between the fingers; $G = 2.174$. Color and streak milk-white, inclining to blue; fracture conchoidal; adheres strongly to the moistened lip. Yields water in matrass; flies in pieces, in platin-forceps, becoming opaque, gray, and at length white, without fusion; borax and mic. salt dissolve it to a clear glass, leaving a skeleton of silica in the latter; with nitrate of cobalt gives a dirty grayish blue. The greater part is decomposed by chlorohydric acid, forming a jelly. Composed of silica 86.60, lime 6.25, alumina 2.23, water 4. = 99.08. Occurs at Milchsachsen, near Eibenstock, Erzgebirg. Separated from opal and described by Breithaupt, and analyzed by Kersten.

ALUMS. *Chem.* There are various compounds, resembling common alum in their atomic composition, in which the potassa may be replaced by another protoxide, and the alumina by another sesquioxide, and yet they all crystallize in the same system with common alum. As they illustrate the theory of isomorphism, they are here presented in a tabular form, with their names and formulæ. The 5th and 6th have not been observed crystallized in the regular system, and are not, therefore, true alums, but are merely introduced from their similarity of composition.

Table of the Formulæ of Alums.

Common or Potassa Alum.....	$\text{KO}, \text{SO}_3 + \text{Al}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{aq.}$	See ALUMINUM .
Soda "	$\text{NaO}, \text{SO}_3 + \text{Al}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{aq.}$	ditto.
Lithia "	$\text{LO}, \text{SO}_3 + \text{Al}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{aq.}$	ditto.
Ammonia "	$\text{NH}_3, \text{HO}, \text{SO}_3 + \text{Al}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{aq.}$	ditto.
Manganous-magnesia "	$\text{MnO} \left\{ \text{HO}, \text{SO}_3 + \text{Al}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{aq.} \right.$	See ALUM, Min.
Ferrous "	$\text{FeO}, \text{SO}_3 + \text{Al}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{aq.}$	ditto.
Ferric-potassa "	$\text{KO}, \text{SO}_3 + \text{Fe}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{aq.}$	See IRON .
Ferric-ammonia "	$\text{NH}_3, \text{HO}, \text{SO}_3 + \text{Fe}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{aq.}$	ditto.
Manganic "	$\text{KO}, \text{SO}_3 + \text{Mn}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{aq.}$	See MANGANESE .
Chromic "	$\text{KO}, \text{SO}_3 + \text{Cr}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{aq.}$	See CHROME .
The general formula is.....	$\text{RO}, \text{SO}_3 + \text{R}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{aq.}$	

And it is probable that others may be discovered, but different proto- and sesqui-bases; or even the sulphuric acid may be replaced by

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selenic or chromic acid, so that we can imagine an alum to be formed that will contain not one of the constituents of common alum excepting the water. See ISOMORPHISM.

ALUNITE. *Min.* See ALUM-STONE.

ALUNOGEN. *Min.* Syn. Sulphate of alumina. *Ger.* Haarsalz, Federalaun (in part). *Fr.* Alunogene, *Beudant*.

Descrip. Very soft. $G=1.66$. Efflorescence, fibrous, or fine-grained crystalline; color white,

sometimes yellowish or grayish; lustre silky; translucent; soluble in water; taste and behavior before the blowpipe similar to alum.

Analysis of Alunogen from the crater of Pasto, and from Saldana in Colombia by Boussingault; from Coquimbo, Chili, by H. Rose; from the brown coal of Kolosoruk, near Bilin, of Friesdorf, near Bonn, from the alum-slate of Potchappel, near Dresden, and from the alum-earth of Freienwalde, by Rammelsberg.

	Freienw.	Potschap.	Friesdorf.	Saldana.	Chili.	Pasto.	Kolosor.
Sulphuric acid....	35.637	35.710	37.380	36.4	36.97	35.68	35.82
Alumina.....	11.227	12.778	14.867	16.0	14.63	14.98	15.57
Water (and loss) ..	48.847	47.022	45.164	46.6	44.64	49.34	48.61
Protox. of Iron....	0.718	0.667	2.463	($Fe_2O_3=0.004$)	2.58)	—	—
Protox. of Mangan.	0.307	1.018	—	($SiO_3=$ —	1.37)	—	—
Magnesia.....	1.912	0.273	—	0.004	0.14	—	—
Lime.....	0.449	0.640	0.149	0.002	—	—	—
Potassa.....	0.473	0.324	0.215	—	—	—	—
Silica.....	0.530	—	—	—	—	—	—
	100	98.432	100.238	99.010	100.33	100.00	100.00

The formula is therefore $Al_2O_3, 3SO_3 + 18 aq.$, which is the same as the artificial salt, or hydrous neutral sulphate of alumina.

Göbel describes a white efflorescence from Ararat, which, according to his analysis, consists of alumina 38.75, sulphuric acid 58.58, protosulphate of iron 2.78 = 100.11, and corresponds to the formula $Al_2O_3, 2SO_3$, which is $\frac{2}{3}$ sulphate of alumina. The water was not determined.

Berthier describes another salt from Huelgoëth in Bretagne, for which he gives the formula, $2Al_2O_3, SO_3 + 12 aq.$, but it does not exactly accord with his analysis. *Rammelsberg*.

AMALGAM. *Chem.* An alloy of mercury with another metal. Mercury unites with many metals at ordinary temperatures, for others it has a feeble affinity. Morveau attempted to measure the force of adhesion by suspending plates of different metals from one of the arms of a balance to the surface of mercury, and observing the weights required to separate them: but such a method cannot be regarded as accurate, since an amalgam may be formed, which would vary the result. See *Amalgams* under MERCURY; refer also to ALLOY.

AMALGAM. *Min.* Syn. Dodecahedral mercury. *Fr.* Mercure argental.

Descrip. Cryst. in the regular system, the dodecahedron predominates, sometimes combined with the cube, 8-hedron, 24-hedron, 48-hedron, and 4×6 -hedron. Also massive. $H=1-3.5$. $G=10-14$. Color grayish or silver-white; lustre metallic; fracture flat, conchoidal; brittle; sectile, with a grating noise.

Analysis of Am. from Moschellandsberg, Rhenish Bavaria, by Heyer and Klaproth, and from another locality by Cordier.

	Klaproth.	Heyer.	Cordier.
Silver.....	36	25.0	27.5
Mercury.....	64	73.3	72.5
	100	98.3	100.0

The 1st is nearly $AgHg_2$; the two last $AgHg_3$. *Behavior.* Boils and spirits in the matrass;

sublimes mercury, leaving a porous mass of silver. Soluble in nitric acid.

AMALGAMATION. *Met.* The metallurgic process by which gold and silver are separated from their ores, is termed amalgamation, from the employment of mercury, which unites with those metals, collecting them in a small compass as an amalgam. The metal is obtained by subjecting the amalgam to heat. See GOLD and SILVER.

AMANITIN. *Chem.* The poisonous principle in certain species of the mushroom tribe. See MUSHROOM.

AMARYTHRIN. *Chem.* See LICHENS.

AMAZON-STONE. *Min.* See FELSPAR.

AMBER. *Tech.* Syn. *Lat.* Succinum (from Succum, juice), Electrum (from $\epsilon\lambda\epsilon\kappa\tau\rho\nu$). *Ger.* Bernstein. *Fr.* Succin.

It is frequently included among minerals, with which, however, it can no more be classed than the resin copal, found in the sands of Africa. It is a substance of vegetable origin, resembling copal and some other resins in appearance, and in some of its physical and chemical properties, and like them is employed for varnishes. The variation of its properties from those of resins is not perhaps greater than is to be found among the different resins, or may be in part attributed to a slight and gradual alteration due to the time of its exposure to the various natural agents. From some of its chemical and physical properties, its occurrence in or near coal, its enclosing insects like cherry-tree gum, &c., it is usually supposed to be a resin derived from trees of the same geological age with the Upper Secondary or Tertiary strata; but from the formation of succinic acid from fat, as well as from amber, we might suppose it to have been a species of wax, or of a fatty nature. Its balsamic or resinous origin is more probable than the latter view.

It is most abundantly found on the Prussian coast of the Baltic, Courland, Livonia, Pomerania, and in Denmark, where it is often washed up on the shore by the waves, after the autumnal storms; or it is dragged up by a net; or ob-

tained by mining. In the latter case a stratum of sand, then of loam, are pierced, neither containing amber, but below the latter occurs a bed of lignite, in and near which it is obtained. From the cones found near it, we may attribute the amber to the balsam of certain extinct species of *Coniferæ*, which has hardened by the loss of its volatile oil. It frequently contains insects of various genera and species; among them several genera of spiders, no species of which is now in existence. Some genera of these insects are still found in South America and New Holland, but the species are extinct; and but a single living insect, found in America, has been observed in amber, viz. *Lepisma saccharinum*. It is sometimes, but rarely, found on the Scandinavian coast; other localities are Hasen Island, Greenland, near London in sand, and Paris in clay, in Italy, on the Sicilian coast, in Spain, Siberia, China, United States. In the United States it occurs in the (red) clay formation subjacent to the green sand, and sometimes in the green sand itself. In the clay formation in the United States, it is frequently associated with lignite, occurring on Martha's Vineyard; from Amboy to below Camden, New Jersey; in the clays and sands of the Deep Cut on the Delaware and Chesapeake canal, and in the green sand in Delaware; farther at Cape Sable, Maryland. It is said that Prussia draws an annual revenue of 17,000 rixdollars from this substance.

It is found of variable sizes; a specimen in the Royal collection at Berlin weighing 18 lbs. Colors, usually some shade of yellow, colorless, light and brownish yellow, reddish orange, brownish black; transparent, translucent, opaque, sometimes milk-white and opaque, different colors and degrees of transparency occurring in the same piece; lustre resinous; rather brittle, with conchoidal fracture, and a soft feeling, shining surface; receives a good polish, and hence carved into ornaments. $H = 2-2.5$, being harder than most resins. Spec. grav. 1.065—1.075. By friction on woollen cloth becomes strongly negative electric.

Heated in the air, it fuses at about 549°, evolving an agreeable aromatic odor, and burns with a clear flame. By fusion it is decomposed and its properties altered, giving off volatile matter and leaving a clear, brownish, translucent resin, which is almost insoluble in alcohol, partially soluble in ether, and most perfectly in fixed and volatile oils, with a brownish yellow color. Slowly heated in linseed oil to boiling, it is soft and flexible, without fusing or decomposing, and unless cooled slowly in the oil, is as brittle as glass; opaque spots are thus often rendered translucent. *Berz.*

Amber is wholly insoluble in water; absolute alcohol and ether become yellow in contact with it powdered, extracting succinic acid and resin. It is soluble with a brown color in oil of vitriol, from which water precipitates the greater part of a yellow color, which retains a little of the acid; by boiling with sulphuric acid, tannin and charcoal are produced. Nitric acid changes it to a yellow resin, which gradually dissolves in the acid. Finely powdered, and boiled with solutions of caustic or carbonated alkali, much succinic acid is extracted;

and pure water extracts resinated alkali from the residue, leaving amber bitumen. *Berz.*

Amber contains a volatile oil, succinic acid, 2 resins soluble in alcohol and ether, and a peculiar bituminous substance, insoluble in all solvents, and constituting the greater part of the amber. When finely powdered, and digested with ether in a stoppered vessel, renewing the solvent as long as any thing is dissolved, 10—12 per cent. are extracted. By distilling off the ether from water the residue is a balsam, probably that which originally exuded from the tree; and by distilling the balsam with the water, the volatile oil passes over, while succinic acid is dissolved in the water and the 2 resins float on the solution. See *Succinic Acid*. The oil is rather soluble in water, has a strong odor of pepper and rosemary, tastes at first cooling, then warm, aromatic, finally biting.

The two resins are separated by cold alcohol of 0.84, which dissolves one, leaving the greater part of the other; or better by heating the alcohol, when the 2d separates on cooling as a powder; by spontaneous evaporation still more is deposited. The 1st or soluble resin obtained by evap. the alcohol, is clear, soft, and smells of vol. oil of amber, fuses perfectly at 212°, is very soluble in alcohol and ether, and in alkali with a yellow color, and after drying the latter, it is soluble in water. The second or powdery resin is soluble in abs. alcohol, and by spontan. evaporation, remains as a light, voluminous, snow-white powder. It fuses with difficulty, forms a colorless solution with alkali, which, after evap. to dryness, swells in water, and but partially dissolves; acids precip. from this solution the hydrated resin.

The amber-bitumen insoluble in menstrua, forms a light, yellow powder, which, heated in air, becomes brown, without fusing; by dry distillation it yields a colorless, empyreumatic oil, fuses and then gives a yellowish empyr. oil, leaving but little charcoal. If the process be stopped, when the mass is fully fused, the resinous mass remaining is the chief constituent of amber-varnish. Alcohol extracts a minute quantity of resin from this residue; then ether extracts more, and subsequently oil of turpentine or naphtha extract more still, leaving a light-yellow, transparent, elastic substance. Spt. turpentine and fixed oils readily dissolve the fused bitumen by the aid of heat, leaving the same elastic substance. By fusing the bitumen with caustic potassa, an empyreum. oil passes off, and the alkaline resinate dissolves in warm water with a brown color, from which chlorohydric acid throws down a whitish gray hydrate. The latter fuses, giving off water, to a hard, transparent, dark-yellow resin, slightly soluble in absol. alcohol, much more in ether, and wholly in spt. of turpentine.

The analysis of amber by Drapiez, gives the following composition: carbon 80.59, hydrogen 7.31, oxygen 6.73, ashes 3.27, loss 2.1; the ashes consisted of silica 0.63, alumina 1.1, lime 1.54. An analysis of this substance from one locality is of little value.

Dry distillation of Amber. The products of its dry distillation are employed in pharmacy and for a varnish.

AMBER.

AMBER.

This distillation is performed in a retort, a copper or iron still, $\frac{2}{3}$ filled with amber, and slowly heated. The products are first acid water, then succinic acid and a colorless oil, then a brown and viscid oil, and when the acid ceases to pass over, a yellowish, wax-like substance, a pyro-resin, called volatile amber-resin or camphor. The acid water contains succinic and acetic acids.

The *empyreum. oil* is brownish yellow and thick, the latter portions dark brown, viscid and tough; a strong, disagreeable odor; distilled with fresh charcoal, it is nearly colorless or pale yellow, thin, of a penetrating odor, a sharp, empyreum. taste, called *Rectified Oil of Amber*; it has an acid reaction, is apt to become browner and more viscid. 1 rectif. oil dissolved in 24 alcohol (of 0.83) and mixed with 96 caustic ammonia (of 0.916), forms a kind of emulsion, the *Eau de Luce*. The oil is employed in medicine internally and externally, and is a powerful local irritant.

Drapiez extracted a pyro-resin and pyro-oil from the empyr. oil, and subjected it to analysis, *a*; the insoluble part *b* yielded to ether a pyro-resin *c*, while an insoluble, opaque, yellow, shining crystalline mass *d* remained. By analysis they consist of

	<i>a.</i>	<i>b.</i>	<i>c.</i>	<i>d.</i>
Carbon.....	75.53	81.08	78.80	79.87
Hydrogen....	14.04	12.87	12.82	14.92
Oxygen.....	10.63	6.05	8.58	5.21

The wax-like *pyro-resin* at the close of the distillation is probably the preceding cryst. substance *d*. It is purified by boiling with water to remove the oil, then melted alone, powdered and extracted by ether. A yellow substance, fusible between 176° and 212°, sublimes entire at 212°, forming yellow, shining, micaceous scales, without odor or taste, insoluble in water and cold alcohol, very slightly in boiling alcohol, rather more in cold and hot ether, in volatile and fixed oils; heated in the air, it inflames at about 212°.

Elsner re-examined the oil of amber, which, after being well rectified, had a spec. grav. = 0.8795 at 61°, and contained in 100 parts,

Carbon	84.00
Hydrogen	8.60
Oxygen	7.40
	100.00

When heated by a lamp in a glass retort, it boiled at 266° and violently at 284°, while a colorless oil passed over and the boiling point rose; even at 500° the colorless oil passed over, while the residue was brown and tenacious.

The oil of amber mixed with 16—20 times its vol. of oil of vitriol, separated into 2 fluids, the lower brown, and the upper a clear oil.

	Experim.	Equiv.
Carbon.....	32.41	15
Hydrogen.....	2.90	8
Nitrogen.....	4.43	1
Oxygen.....	20.62	7
Oxide of lead.....	39.64	1
	100.00	

The clear oil washed with water again parted into a light oil above and a milky opaque liquid. The milky liquid evaporated gave a whitish gray substance, fusible at 104°, at a higher heat burned with a strong sooty flame, insoluble in hot and cold alcohol, unchanged by warming with caustic potassa or oil of vitriol. It, therefore, bears some analogy to Paraffine or allied substances.

The light oil, after contact with dry chloride of calcium, by distillation yielded a limpid oil, the first portions pure, the latter impure, while the boiling point of the residue rose above 500°. The clear oil dissolved iodine with a red color without fulminating; potassium was unchanged in it even by warming, made grease spots on paper, disappearing by heat, soluble in alcohol of 0.810, in ether, volatile and fixed oils. Treated with fuming nitric acid it yielded artificial musk of very decided properties.

Elsner terms this oil Succin-eupione. It consists of

	Experiment.	Equiv.	Calcul.
Carbon.....	84.548	32	84.58
Hydrogen....	11.983	27	11.89
Oxygen.....	3.469	1	3.53

If we suppose it to consist of an anoxygenuous carbo-hydrogen, the formula might be $C_{35}H_{29}O$; and the rational formula, $7(C_5H_4) + HO$.

Action of Nitric Acid on Oil of Amber. When 1 part oil of amber is gradually added to 3 pts. fuming nitric acid, a resinous substance is formed, which has been long known and termed artificial musk. Elsner has rendered it very probable that it is due to the oxidation and nitroization of his succin-eupione, and hence terms it *succin-eupione resin*. He prepared it in the above manner, taking care to avoid the evolution of heat. The resin is edulcorated with water to remove the acid and evaporated to a thick syrup; color dark reddish brown, in fine threads transparent, hyacinth-red, very soluble in ether, alcohol, and volatile oils; its odor, especially in solution and in small quantities, very like musk; taste, burning, bitter, aromatic. The alcoholic solution, decolorized by chlorine or sulphurous acid and treated with water, gives a white precipitate of the odor of musk; its tincture gives with the tinctures of chlorides of copper or mercury or of nitrate of silver, no change, with the alcoholic solution of acetate of lead, a pulverulent yellowish brown precip., wholly soluble in an excess of the lead-salt, but not in an excess of the resinous tincture; the lead precip. is edulcorated with alcohol, suspended in water, sulphuretted hydrogen passed through the mixture, the resin extracted from sulphuret of lead by alcohol, and evaporated to dryness. It is the pure resin, without a trace of crystalline structure; subjected to analysis it yielded

	H = 1.	O = 100.	Calculated.
Carbon.....	90	1125	32.15
Hydrogen.....	8	100	2.86
Nitrogen.....	14.16	177	5.06
Oxygen.....	56	700	20.01
Oxide of lead.....	111.73	1394.5	39.92
	279.89	3496.5	100.00
			141

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The resin, therefore, contains in 100 pts. calculated from the lead-salt

Carbon	53.52
Hydrogen	4.76
Nitrogen	8.42
Oxygen	33.30
	100.00

Formula, $C_{15}H_8NO_7$.

According to Setterberg, it contains at least 3 resins, 2 of which are soluble in boiling oil of turpentine, one precipitates on cooling, and the other is obtained by evaporating the oil of turpentine. All 3 form soluble resins with the alkalis of a bitter taste; 1 pt. artificial musk dissolved in 8 alcohol is a medicinal tincture rarely employed. (*Elsner in Jour. f. pr. Chem.* xxvi. 97.)

From the value of amber, it is sometimes adulterated by copal and other resins; these, however, do not yield succinic acid. Where the chief object is to obtain the oil, the adulteration is less injurious, since copal forms an oil of allied properties.

To work amber ornamentally, it is split on a leaden plate at the lathe, and ground more nicely by a whetstone; it is polished on the lathe by chalk and oil, and smoothed by flannel. As it tends to become heated and brittle by friction, different pieces are alternately worked. Pieces are joined by putting linseed oil on the edges, and exposing them to heat, while tightly compressed. See farther **Succinic Acid** and **VARNISH**.

AMBERGRISE. Syn. Ger. Ambra. Fr. Ambre gris. Its origin is uncertain, but it is most probably a product of disease of the spermaceti whale (*Physeter macrocephalus*), and is rather analogous in properties to cholesterin. It is found floating on the sea, especially on the coasts of Madagascar, Coromandel, the Moluccas, and Japan. It is an opaque solid, of a gray color externally, internally lighter gray, with reddish, yellowish, and dark streaks. Spec. grav. = 0.908—0.92. By warmth or friction, gives a rather agreeable odor; the warmth of the hand softens it like wax. Its chief constituent is ambrein; a volatile oil, benzoic acid, and often excrementitious matter of the whale are also present. John's analysis of ambergrise gives 85 ambrein, 2.5 alcoholic extract, 1.5 aqueous extract, containing benzoic acid and chloride of sodium, 11 loss = 100.

AMBREIN. Syn. Ger. Ambrafett, Amberstoff. By saturating boiling alcohol of 0.833 with ambergrise, ambrein crystallizes out on cooling, in delicate, colorless needles, grouped together, from which the liquor is pressed out; more is obtained by evap., but must be purified by recrystallization. Ambrein is tasteless, has an agreeable odor, which does not appear to belong to it, being removed by being kept in fusion; fuses between 86° and 104°, nearly all distils over unaltered; equally soluble in cold and warm alcohol (more in hot, *Liebig*), retaining a portion after evaporation; very soluble in ether, and fixed and volatile oils; not saponifiable by alkalis. Nitric acid converts it into

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ambreic acid. Pelletier found it to consist of carbon 83.37, hydrogen 13.32, oxygen 3.31, which agrees with $C_{33}H_{32}O$.

AMBREIC ACID. Syn. Ger. Amberfett-säure, Ambrasäure. Act upon ambrein by boiling nitric acid, adding the acid until nitrous vapors cease, evaporate to dryness, wash several times with cold water, boil the residue with water and white lead to remove nitric acid, till acid reaction nearly ceases, wash out nitrate of lead with water, and dissolve the residue in boiling alcohol. This clear solution deposits ambreic acid by cooling and evaporation in small, slightly yellowish laminæ, tasteless, with a peculiar odor, fuses above 212°, has a slight acid reaction, scarcely soluble in cold or boiling water, very soluble in ether and alcohol. Part of the constituents of the nitric acid have combined with the ambrein, but Pelletier's analysis is probably incorrect, giving the formula $C_{13}H_{10}N_3O_6$.

The salts of ambreic acid are yellowish. Ambreate of potassa is very soluble; biambrete insoluble in water, soluble in alcohol. The acid dissolved in potassa and neutralized with acetic acid, produces yellow precipitates with baryta, lime, protox. of iron, oxide of lead, protox. of tin, oxide of copper, oxide and suboxide of mercury, oxide of silver, and from chloride of gold, but the last is soon reduced to the metallic state.

Uses. Ambergrise is rarely employed in medicine, its effects being analogous to musk. It is chiefly used as a perfume, dissolved in alcohol.

AMBLYGONITE. Min. Syn. Amblygonic Augite Spar, from ἀμβλύγωνος, *obtuse-angled*.

Descrip. Cryst. apparently right rhombic system, occurring in prisms of 106° 10' and 73° 50', with rough surfaces; cleavage parallel to planes of prism, with brilliant surfaces. Occurs also massive. H = 6.5. G = 2.3—3.0. Color, greenish white, sea-green; lustre vitreous, nearly pearly on planes of cleavage; in thin laminæ translucent, transparent; uneven fracture.

Behavior. In matrass gives moisture, which, with strong heat, is acid, and attacks the glass; fuses on charcoal, even in a candle, to a clear glass, which clouds on cooling; dissolves in borax and mic. salt to a clear glass; fuses with little soda, with more it swells and is infusible; moistened with sulphuric acid, colors the flame bluish green; when alone or mingled with fluorspar and bisulphate of potassa, gives a more yellow than red flame.

Analysis. Composition doubtful; Berzelius found about 11 per cent. lithia in it, and gives the formula, $2 LO, PO_5 + 4 Al_2O_3, 3 PO_5$, which is neutral phosphate of lithia and basic phosphate of alumina. The yellow soda-flame shows that it requires re-examination. *Berz. and Rammelsberg.*

Locality. Only at Chursdorf, near Penig, Saxony, associated with turmaline and garnet.

AMETHYST. Min. See **QUARTZ**.

AMIANTHOIDE, AMIANTHUS. Min. See **HORNBLende**, *Actynolite*, *Asbestos*.

AMIDE, AMIDOGEN. Chem. A compound of nitrogen and hydrogen, generally admitted, although not isolated. It is known in

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combination with a few metals and organic substances, and seems to be a salt-radical, like oxygen, chlorine, sulphur, &c.

When potassium is heated in ammoniacal gas, it decomposes the gas, liberating a little more than $\frac{1}{3}$ of the hydrogen, and combining with the remainder. K and $NH_3 = K, NH_2$ and H . This compound is olive-green, fusible, and although not obtained perfectly pure, is believed to contain the above compound. The compound NH_2 is called amidogen or amide, from Dumas's researches on oxamide.

When oxalate of ammonia (NH_3, HO, C_2O_3) is distilled, a white compound sublimes, which is termed oxamide, and may be regarded as a compound of carbonic oxide and amide; it is formed by the removal of two equivs. of water. $NH_3, HO, C_2O_3 = NH_2, C_2O_2$ and $2HO$.

Kane regards amide as the radical of all the compounds of ammonia, as well as of those bodies usually termed amides. Without adopting this view, although it may be defended, we must believe amide to be a radical which exists in a few compounds. Its symbol is NH_2 or Ad , and its equiv. 16.19 ($H=1$) or 202 ($O=100$). The following table comprises some of its compounds:

$NH_2 = Ad$	Amide.
$NH_2, H = Ad, H (?)$	Ammonia
$NH_2, H_2 = Ad, H_2 (?)$	Ammonium
$NH_2, K = Ad, K$	Amide of potassium.
$NH_2, K = Ad, Na$	Amide of sodium.
Ad, SO_2	Sulphamide
Ad, CO	Carbamide
Ad, C_2O_2	Oxamide. <i>Dumas</i> .
$HgAd, H_3Cl$	White precip., or chloramide of mercury.

	Bucholz.
Resin.....	72.0
Gum.....	22.4
Gluten (Bassorin?).....	1.6
Vol. oil, water, and loss.....	4.0

AMMONIUM.

See Sulphamide and Carbamide, under SULPHURIC and CARBONIC ACIDS; Oxamide, Benzamide, &c., under OXALIC, BENZOIC, &c. acids; White precipitate, &c., under MERCURY; see also under AMMONIUM.

AMIDES, AMIDIDES, AMIDURETS. *Chem.* Compounds of amide (amidogen). The first term is more generally employed.

AMIDEN. *Chem.* Syn. Amidin. The inner portion of the grains of starch, constituting $99\frac{1}{2}$ per cent. of the whole. See STARCH.

AMILEN. *Chem.* See AMULE.

AMMELID, AMMELIN. *Chem.* Both derived from Melam, which is a product of decomposition of sulphocyanide of ammonium. See CYANOGEN.

AMMONIA. *Chem.* A compound, consisting of nitrogen and hydrogen, NH_3 , which acts like the alkalies, potassa and soda, and hence it may be regarded as the oxide of a metal. See AMMONIUM.

AMMONIAC. *Phar.* A gum-resin, the hardened milky juice of the *Dorema Ammoniacum* (*Armeniacum*), obtained in Persia. It occurs in tears (grains) or massive; externally yellowish or reddish, internally milk-white, often containing sand, twigs, &c.; when cold, it is brittle and pulverizable; softens in the hand, but does not fuse even with a higher heat. Spec. grav. 1.207. Its odor is disagreeable, arising from volatile oil; its taste at first sweetish, then nauseous, acrid.

By distillation with water it loses its odor and volatile oil; distilled alone, it yields 22 acid water, containing ammonia, 12 of a thin, and 19 of a thick empyreum. oil, and leaves 32 charcoal, which contains 1.1 ashes. It has been analyzed by Bucholz, Braconnot and Hagen.

	Bucholz.	Braconnot.	Hagen.
Resin.....	72.0	70.0	68.6
Gum.....	22.4	18.4	19.3
Gluten (Bassorin?).....	1.6	4.4	5.4
		loss 1.2	extractive 1.6
Vol. oil, water, and loss.....	4.0	water 6.0	2.8
			sand 2.3

The resin, separated by alcohol, is reddish, transparent, tasteless, has the odor of the gum-resin; softens in the hand, melts at 130° ; very soluble in alcohol; ether separates it into two resins, one insoluble; soluble in fixed and volatile oils and sulphuric acid; nitric acid converts it into a bitter substance; alkalies form a cloudy solution.

The gum is reddish yellow, somewhat bitter, changed by nitric acid into mucic, malic, oxalic acids, &c. Its aqueous solution precipitated by subacetate of lead. The oil is transparent, colorless, lighter than water.

Use. In medicine externally and internally, resembling asafœtida.

AMMONIUM. *Chem.* Syn. Subamide of hydrogen. *Kane*. The hypothetical metallic basis of ammonia and its salts. The following theories show the different views entertained of the nature of ammonia.

1. *Former view*. Ammonia, NH_3 , is an alkali, forming salts with oxy- and hydracids without alteration. With chlorohydric acid it forms (sal-ammoniac) chlorohydrate of ammonia, NH_3, HCl ; it unites with the hydrate of an

oxyacid, thus sulphate of ammonia = NH_3, HO, SO_3 .

2. *Berzelius' Ammonium Theory*. When ammonia, NH_3 , unites with a hydracid (chlorohydric), it takes the hydrogen of the acid and forms ammonium NH_4 , which then unites with the radical of the acid, forming a haloid salt; thus, sal-ammoniac = NH_4, Cl . With an oxyacid it forms a salt of the oxide of ammonium; thus sulphate of ammonia = NH_4O, SO_3 . By the old theory the equivalent of water is separate. Ammonium is therefore a compound metal or a compound acting like a metal, and hydrated ammonia is the oxide, $NH_3, HO = NH_3, O$.

This theory has the advantage of explaining the similarity of the salts of ammonia, with 1 equiv. water, with corresponding salts of potassa, with which hydrate of ammonia is isomorphic; of explaining the similarity of sal-ammoniac with metallic chlorides, &c.; of removing the only objection to the theory of chlorides not being chlorhydrates: of explaining the formation of the ammoniacal amalgam (see below). The objections to this theory are

not very strong, the best being that we must suppose a very strong affinity of chlorine to ammonium to believe that ammonia can remove hydrogen from chlorohydric acid: that phosphuretted hydrogen PH_3 , similar to ammonia NH_3 , forms similar compounds with iodo- and bromohydric acids, which by the older view would be PH_3, HI ; but by reasoning from the ammonium theory should be PH_4, I , thus obliging us to suppose a metal PH_4 .

3. Kane's *Amide-Theory*. Amide NH_2 is a feeble salt-radical, and with 1 eq. hydrogen, forms ammonia or amide of hydrogen, H, NH_2 or H, Ad , which is a base, resembling water HO , and both belong to Graham's magnesian family of isomorphous bodies. It thus unites with hydracids as chlorohydric, forming chloramide of hydrogen, HAD, HCl (sal-ammoniac). It combines also with a few dry oxyacids: thus sulphate of ammone, HAD, SO_3 , is like oil of vitriol, HO, SO_3 . Ammonium, NH_4 , is subamide of hydrogen, H_2Ad , and the oxide of ammonium, NH_4, O , is a double base, the oxyamide of hydrogen, HAD, HO . In the common oxysalts of ammonia, 1 eq. acid is united with 2 eq. base: thus sulphate of ammonia = $\text{HAD}, \text{HO}, \text{SO}_3$. While HAD is isomorphous with the magnesian family, HAD, HO is isomorphous with potassa and soda: it would hence appear that two equivs. of base of the magnesian family may replace potassa or soda.

Much may be said in favor of each of these theories, but perhaps no one of them will apply to all cases, for each may be correct to a limited extent. Thus we may hold that amide NH_2 is a compound body analogous to chlorine, oxygen, &c., entering into some combinations, without applying it to the ordinary salts, and many other compounds of ammonia. NH_3 may be viewed as a salt-radical, without regarding it as oxide of ammonium or amide of hydrogen, and it is probably isomorphous with the bases of the magnesian class. NH_4 acts like a metal in the ordinary salts of ammonia and some other ammoniacal compounds, and may be viewed either as such or as a base like ethule, benzule, &c., in which case it should be termed *Ammonule*. NH_4O or NH_3, HO is another saline base, isomorphous with potassa and soda, and may be regarded either as oxide of ammonium, or as ammonia and 1 eq. water.

AMMONIUM, AMMONIA, AND COMPOUNDS.

1. *Ammonium*. NH_4 not isolated; if it exist in a nearly free state, it is in the ammoniacal amalgam, which, however, may be viewed as an amalgam of hydrogen. See MERCURY.

2. *Ammonia, Gaseous*. NH_3 . Syn. Volatile alkali, Alkaline air. Ger. Ammoniak, Fluchtiges Alkali oder Laugensalz, Alkalische Luft. Fr. Ammoniaque; by Kane Hydramide, Amide of Hydrogen. Sal-ammoniac was formerly prepared in the province Ammonia in Lybia, whence the name.

Locality. Occurs in the air, and consequently in rain or snow and river water, as carbonate or nitrate; in sea-water, in rock-salt rarely, in many mineral waters combined with sulphuric, muriatic acids, &c.; in iron rust and many native oxides of iron, sometimes at great depths, in most clays; in the juices of many

plants, in most animal fluids; in vegetable mould, and where animal and some vegetable matters are decomposing.

Formation. From *inorganic* substances. When hydrogen in excess is burned in the air, the nitrate of ammonia is formed. Hydrogen, in its nascent state, in contact with nitrogen or atmospheric air, often forms ammonia; when iron rusts in the air, from the decomposition of water, a mixture of iron-filings and water, or moistened iron-filings and sulphur; when hydrates of potassa, soda, baryta, or lime are heated in air or in hydrogen with potassium, iron, zinc, lead, tin, or arsenic. Its formation in hydrogen is shown by Reiset to proceed from nitric oxide, derived from the sulphuric acid used to prepare the hydrogen; for when iron-filings are heated in a strong solution of caustic potassa to 266° , it evolves hydrogen and ammonia, both in air and in hydrogen containing nitric oxide, but not in pure hydrogen.

It is also formed when nitrogen is in its nascent state; thus, when nitric oxide and hydrogen are passed over warmed platinum-sponge (*Hare*), or passed through an ignited tube containing porous substances, such as powdered pumice, oxide of iron, &c., the alternate reduction and oxidation of the metal undoubtedly assisting. *Reiset*. Nitrous oxide and an excess of hydrogen passed over cold platinum black or sponge are unaltered, over heated, yield much ammonia. Cold platinum black or sponge does not act on hydrogen charged with nitric acid; when heated, all the nitrogen is converted into ammonia, the sponge becoming ignited. *Kahlmann*.

Ammonia is farther formed when both nitrogen and hydrogen are rising from combination, in the nascent state. Thus, when iron and zinc decompose water with the presence of nitric or hyponitric acids or nitric oxide, it is always formed, whether by heat or in the cold. Cadmium and tin dissolved in nitric acid, take oxygen not only from the acid, but also from the water, and thus hydrogen being set free, ammonia is generated. A mixture of 100 vols. water with 4.5 vols. sulphuric and 4 vols. nitric acid, dissolve iron, zinc, or tin, evolving neither nitric oxide nor hydrogen, the latter uniting with the nitrogen of the former to form ammonia.

It is formed from *organic* substances, even when they contain no nitrogen, as when sugar, linen, oxalates, &c., are heated with hydrated potassa, soda, or lime, in a vessel to which the air has access; or when some organic bodies are heated with nitric acid or oxide, or a nitrate. It is, however, chiefly produced by the decomposition of nitrogenous organic substances, as by their dry distillation, or heating them with potassa, by fermentation, putrefaction, &c. See Will and Varrentrapp's method of determining nitrogen in an organic ANALYSIS.

Preparation. By gradually heating a mixture of dry and powdered chloride of ammonium (sal-ammoniac) and lime, and receiving the gas over mercury.

Properties. Gaseous, colorless; its odor extremely pungent, revivifying, irrespirable when pure, but may be breathed when diluted with air; taste strongly alkaline; browns turmeric

AMMONIUM.

even when dry, changes reddened litmus to blue; very slightly combustible, and extinguishes burning bodies; a small jet passed into oxygen burns with a small yellow flame. Calculated spec. grav. = 589.3.

When subjected to a pressure of 6.5 atmospheres at the temperature of 50°, or at common pressure and the temperature of -40°, it is liquefied. A very thin, colorless liquid, of spec. grav. 0.76, refracts light more than water.

Ammonia is decomposed by passing a succession of electric sparks through it, or by passing it through a red-hot porcelain tube containing pieces of porcelain, platinum, gold or silver-wire; 200 vols. become 400 vols.; if copper or iron-wire be employed, they absorb nitrogen. By exploding ammonia with oxygen it is resolved into nitrogen, hydrogen, and water, when the oxygen is insufficient to combine with all the hydrogen, or into nitrogen, water, and nitrate of ammonia, when the oxygen is in excess. It is also decomposed by other gases which readily yield oxygen, either in the cold, by heat, or by the electric spark, generally forming other compounds of nitrogen and water; thus, with nitrous oxide in excess, it yields nitrogen, oxygen, water, and hyponitric acid. With many metallic oxides it yields water, nitrogen, &c. Its most interesting decomposition is when passed over heated charcoal, forming cyanide of ammonium (prussiate of ammonia) and hydrogen, $2\text{NH}_3 + 2\text{C} = \text{NH}_4\text{CN} + 2\text{H}$. See CYANOGEN. Chlorine and iodine decompose its aqueous solution, forming, among other products, the explosive chloride or iodide of nitrogen.

3. *Liquid ammonia.* Syn. Aqua ammoniæ, Caustic Ammonia, Spirit of Hartshorn. *Ger.* Salmiakgeist. *Fr.* Esprit de sel ammoniac.

Ammoniacal gas is absorbed rapidly and in large quantity by water, with the evolution of heat; ice is melted by the gas and the temperature lowered. One vol. water absorbs 60 vols. gas at 50° temp. and 29.8 inches bar., and by expansion, not due to the heat evolved, its spec. grav. = 0.875; the water, therefore, absorbs nearly $\frac{1}{2}$ its weight; by increased pressure or lower temperature, it absorbs more than $\frac{1}{2}$ its weight, and in the latter case its spec. grav. = 0.850. A mixture of equal vols. concentrated ammonia and water appears to expand.

Preparation, Technic. Caustic ammonia is prepared on a large scale, by mixing 1 pt. sal-ammoniac in pieces, or gently calcined sulphate of ammonia, with 1 pt. dry caustic lime, slacked with 3 or 4 pts. water, or so much as to make a cream, introduced into an iron retort, which is connected with a series of stone jars (Woulfe's apparatus), a balloon intervening between the retort and 1st jar to catch any unchanged salt that may distil over. (See the apparatus under MURIATIC ACID.) Heat is applied until all of the ammonia is expelled. The residue is chloride of calcium.

The lime may be previously slacked to a dry powder, or broken into small pieces, and then mingled with the sal-ammoniac, and more water subsequently added; the heat of slacking in the latter case economizes fuel. When too little water is added, the materials are apt to

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adhere to the bottom of the retort, which may be obviated by adding a little common salt to the mixture. The above method with cream of lime is probably the best.

The following tables, by Davy and Ure, show the quantity of dry ammonia in 100 pts. of the liquid by weight. Those marked with a * in Davy's table were determined by experiment, the rest by calculation.

Table of the Strength of Caustic Ammonia.

Davy.		Ure.	
Spec. grav.	Per cent. Ammonia.	Spec. grav.	Per cent. Ammonia.
0.8750	* 32.30	0.8914	27.940
.8857	29.25	.8937	27.633
		.8967	27.038
		.8983	26.751
.9000	26.00	.9000	26.500
.9054	* 25.37	.9045	25.175
		.9090	23.850
.9166	22.07	.9133	22.525
		.9177	21.200
.9255	19.54	.9227	19.875
		.9275	18.550
.9326	17.52	.9320	17.225
.9385	15.88	.9363	15.900
.9435	14.53	.9410	14.575
.9476	13.46	.9455	13.250
.9513	12.40	.9510	11.925
.9545	11.56		
.9573	10.82	.9564	10.600
.9597	10.17		
.9616	9.60	.9614	9.275
.9692	* 9.50	.9662	7.950
		.9716	6.625
		.9768	5.500
		.9828	3.975
		.9887	2.650
		.9945	1.325

Properties. A colorless liquid, possessing most of the properties of gaseous ammonia, loses the greater part of the gas below 200°, solidifies at -36° 4 to -41° 8, in shining, flexible needles, at -56° 2, to a gray gelatinous mass, with scarcely any odor. The very strong caustic ammonia has a spec. grav. = 0.88, and 1 meas. of this and 3 meas. water yield a strong aqua-ammonia of 0.960. To prevent loss of ammonia and absorption of carbonic acid from the air, it should be kept in well stoppered bottles. Ammonia is a strong alkaline base, neutralizing acids perfectly, often abstracting them from other combinations, and forming crystallizable salts. See its uses and combinations below.

Impurities. It may contain sulphate or muriate of ammonia, carried over mechanically, which are tested by neutralizing with pure nitric acid, and adding chloride of barium for the former and nitrate of silver for the latter; if lime or chloride of calcium be carried over, test them by evaporating to dryness; it usually contains empyreum. oil, which colors it yellow when this was present in the ammoniacal salt; by standing in the air, or from the presence of carbonate of lime in the caustic lime used, it may contain carbonate of ammonia.

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To obtain it pure, mix 1 freshly slacked lime with 5 caustic ammonia, distil at a gentle heat $\frac{2}{3}$; or prepare from good sal-ammoniac and lime with glass Woulfe's bottles, rejecting the contents of the 1st, which should contain but little water.

Uses. Largely employed as an agent by the theoretic and manufacturing chemist, to a limited extent in dyeing and other arts, and in medicine. It is invaluable to the analytic chemist, from its strong alkaline character and the volatility of its salts.

Combinations. It combines with acids, forming salts; with many salts, oxides, and metalloid compounds, both in its gaseous and liquid state, and generally by bringing it in contact with them.

SALTS.

The salts with the hydracids are viewed, according to the old theory, as direct compounds: thus, ammonia and muriatic acid = NH_3, HCl ; by Kane's theory as double amides: thus, $\text{NH}_3, \text{HCl} = \text{HAD}, \text{HCl}$, a chloramide of hydrogen; by the ammonium theory, as ammonium with a halogen: thus $\text{NH}_3, \text{HCl} = \text{NH}_4, \text{Cl}$. According to the last, sal-ammoniac is chloride of ammonium, and corresponds to chlorides of potassium and sodium, with which indeed it possesses the same crystalline form; when a metallic chloride is precipitated by ammonia, water is decomposed; thus, with protochloride of iron in solution, $\text{FeCl}, \text{HO} + \text{NH}_3 = \text{NH}_4, \text{Cl} + \text{FeO}$.

The oxyacids usually combine with ammonia only when water is present, forming with 1 eq. HO the ordinary oxyacids of ammonia; dry ammonia and dry oxyacids unite, forming another class of compounds, which Rose terms salts of Ammone; the former may be viewed as salts of oxides of ammonium, the latter as true salts of ammonia. In the common oxyacids, the hydrogen of the equiv. of water is supposed to unite with the metal ammonium, while the oxygen makes it oxide of ammonium. Thus sulphate of ammonia, $\text{NH}_3, \text{HO} + \text{SO}_3 = \text{NH}_4, \text{O} + \text{SO}_3$, or sulphate of oxide of ammonium. We shall designate them all as salts of ammonia, giving among the synonymes their theoretic appellations.

The ammoniacal salts are all colorless with colorless acids and other salts; have a biting, saline taste; are nearly all readily soluble in water; are easily decomposed or volatilized by heat, the haloid salts and carbonate volatilizing without decomposition; the others leaving the acid, if it be fixed (phosphoric acid), or decomposing it (sulphuric acid). Many of them lose a portion of ammonia by keeping, and then test acid. When rubbed dry, or moistened with caustic alkali and some other oxides, they evolve ammoniacal gas, recognised by its odor; or if, in dilute solution, the odor is too feeble, a glass rod, dipped in muriatic acid, and held over it after potassa is added, produces a white cloud of ammoniacal salt. It is precip. from a solution not too dilute by bichloride of platinum, giving chloride of platinum and ammonium, or by a concentrated solution of sulphate of alumina, yielding ammonia-alum.

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HALOID SALTS.

1. *Chloride of Ammonium.* *Tech.* Syn. Sal-ammoniac, Muriate of Ammonia. *Ger.* Chlor-ammonium, Salmiak. *Fr.* Sel ammoniacque, Hydrochlorate d' ammoniacque, Chlorure d' ammonium. Found in the vicinity of volcanoes, in minute quantity in sea-water and salines.

Preparation. By mingling equal volumes of chlorohydric acid and ammonia, they unite to sal-ammoniac with the evolution of heat. It is always procured by the dry distillation of nitrogenous organic matter, either containing muriatic acid or receiving it in a subsequent operation.

MANUFACTURE OF SAL-AMMONIAC.

1. *Egyptian process.* This salt was formerly and exclusively made in Egypt, especially to the east of Lower Egypt, and the name is supposed to be derived originally from the temple of Jupiter Ammon, near which the principal works were situated. The method now pursued is probably the same as in former times.

Dried camel's dung and urine are employed for fire, from the scarcity of fuel. Burned in an imperfect manner, the dung is subjected to a rude dry distillation, and the dense smoke condensed into soot, containing the salt. The soot, taken to the salt-works, is rammed into glass globes coated with clay, till nearly full, and these are placed in openings in a long horizontal flue, where they are heated to a low red heat. The salt sublimes to the top or cooler part, where it forms a solid cake, often closing the orifice, which must be reopened. Towards the close of sublimation the globes split, and, upon removal after cooling, usually fall to pieces. The solid cake of salt is detached and thrown into commerce. It is of inferior quality, of a grayish color, and spongy texture.

2. *European process.* Various animal matters are subjected to dry distillation, yielding tar and ammoniacal liquor, and leaving charcoal, which is employed in the manufacture of Prussian blue, or as bone-black, when bones alone are used. The animal matters are bones, horn, flesh, blood, wool, hair, silk, &c., generally refuse materials from the mechanic arts. They are introduced into cylindric or semicylindric iron retorts, similar to those employed in the gas-works, and, in general, the process is similarly conducted, excepting that the ammoniacal liquor and residuary coal being chiefly required, the heat is not maintained as high. The tubes at the back of the retorts for carrying off the volatile products, do not rise from the top, as in the gas retorts, but project horizontally from the centre or upper part of the back plate of the retort. The retorts are laid horizontally in brick work, from 3 to 12 being in one stack, and heated by several fires; the flame plays freely around them, and is distributed from the fire-places by flues between the fire-bricks of the fire-arch. The whole stack is doubly arched over, the lower arch being perforated with many flues to distribute the flame. The tubes projecting from the back part of the retorts, pass downwards and enter the hydraulic main, from which the

uncondensed vapors pass through a system of tubes cooled by water into several cisterns provided with stop-cocks at different heights, to let off the oil and ammoniacal liquid. The gaseous matter finally uncondensed is usually passed by tubes under the cylinders and burned.

Where the chief object is ammoniacal liquor, the calcination may be a full red heat; where the residuary charcoal is for prussian blue, the heat must not be carried high, and where for bone-black it is pushed beyond this, care being taken not to carry it too far. The condensed liquors hold carbonate and other ammoniacal salts in solution, mixed with much empyreumatic oil, the greater part of which floats on the top. The carbonate of ammonia is not obtained directly from the liquid, it being so volatile that it could not be evaporated without loss; it is therefore converted directly or indirectly into muriate.

It is done most conveniently, where muriatic acid bears a low price, by directly saturating the ammoniacal liquor with muriatic acid, evaporating in a leaden vessel until a pellicle forms on the surface, and running off into the crystallizers, which are wooden vessels, lined with lead.

Another method is to form sulphate of ammonia, either by directly saturating the liquor with sulphuric acid, or by a double decomposition with sulphate of lime (gypsum). In the latter case the liquor is pumped upon a broad and shallow filter of canvass, covered with a layer of moderately fine gypsum to the depth of a few inches; the canvass rests on a hurdle or grating of wooden rods, which are but an inch above the leaden bottom. From this first filter the liquor may flow out to a 2d, 3d, &c., in order to insure complete decomposition. The double decomposition is that sulphate of lime and carbonate of ammonia become carbonate of lime and sulphate of ammonia. A little water passed through the filters carries off any remaining ammoniacal salt, and finally the solution is slightly acidulated with sulphuric acid. It is next evaporated, the oil and tarry matters being skimmed from the top, until it attains a density of 1.16, when it is mixed with common salt (chloride of sodium), with constant stirring and boiling. It is now run off to settle.

The chloride of sodium and sulphate of ammonia are mutually decomposed into sulphate of soda and chloride of ammonium (sal-ammoniac). The clear liquor is then evaporated, during which, sulphate of soda precipitates, from its inferior solubility. The precipitate is raked out, drained, and washed with a little water; the mother liquor is still farther evaporated and run into the crystallizers. The crystals are then dried, and afford a somewhat crude sal-ammoniac.

To obtain it still purer, it is sublimed in vessels of glass or stone-ware of a spheroidal form, with a neck and opening above. The dried salt is introduced and pressed down, and the opening covered by a plate or vessel to confine the vapors. A large number of these flasks are arranged, two abreast, over a long flue, either resting in cast-iron plates, with circular

openings, destined to receive them, or being placed in sand. The fire requires a nice regulation to sublime the salt from the bottom to the upper part of the flask, where it forms a solid white cake of a fibrous structure. The neck of the flask must be kept open by repeatedly thrusting a long screw-shaped steel rod through the consolidating salt, to avoid explosion from the accumulation of vapor within. The contact of iron is injurious from the ready formation of chloride of iron, which sublimes with the sal-ammoniac, imparting to it an orange or yellow tint.

The English method of manufacture is to employ the ammoniacal liquor of the gas-works, and saturate it with sulphuric acid as above. A ton of good coals will yield about 200 lb. of ammoniacal liquor. At the Deptford works 6—700,000 gallons are annually obtained and employed in this manufacture. At the works near Glasgow, 7,200 galls. obtained weekly, are distilled, and to this are added 4,500 lb. sulphuric acid of 1.625; 2,400 galls. sulphate of ammonia of 1.15 are thus obtained, in such a concentrated state as to deposit a few crystals in the vessel containing it. During these operations 900 galls. of tar subside, and 200 galls. of petroleum are skimmed from the surface of the liquid.

Properties. The sal-ammoniac of commerce occurs in the form of the sublimed cake, weighing about one-quarter of a cwt.; it is parallel-fibrous in structure, translucent, white, unless tinged orange or yellow with chloride of iron, remarkably tough, rendering it difficult of pulverization. The sublimed salt is not likely to contain other impurities than the salt of iron mentioned. The crude salt may be adulterated, which can generally be determined by vaporizing a portion; nothing should be left.

Chloride of ammonium may be crystallized from its solution in the 8-hedron, cube, or 24-hedron. 1 pt. dissolves in 2.7 pts. water at 65.7°, with a great reduction of temperature, and the liquid has then a spec. grav. 1.08; soluble in an equal quantity of boiling water, very slightly soluble in alcohol. Spec. grav. of the salt = 1.45—1.528. It has a sharp saline taste, a neutral reaction. Fixed at common temperatures, but slightly heated, volatilizes, without fusing or decomposition, and even rises in small quantity from its boiling solution; spec. grav. of vapor = 0.9255.

It is easily decomposed by heating with potassium into ammonia and hydrogen, leaving chloride of potassium; the same decomposition takes place more slowly with some other metals. Decomposed by basic oxides, it yields 16.78 per cent. water. It gradually loses a little ammonia and tests acid; but if heated nearly to sublimation, its solution in the cold is neutral; its solution in hot water tests acid.

The dry, powdered salt, in a vessel cooled by ice, absorbs a large quantity of dry sulphuric acid vapor, without evolving gas, and becomes a translucent, flexible mass, which gradually becomes hard. It evolves muriatic acid by heating; a few drops of water effect the same violently; exposure to moist air the same slowly.

AMMONIUM.

	H = 1	O = 100	Calcul.
NH ₃	17·16	214·5	31·98
HCl	36·5	456·25	68·02
NH ₄ Cl	53·66	670·75	100

AMMONIUM.

	Berz.	Vol.	Spec. grav.
Ammon. gas	31·95	100	0·29465
Muriat. gas	68·05	100	0·63090
Vapor	100	200	0·92555

Formula, NH₃, HCl, or NH₄, Cl, or HAd, HCl.

Uses. Sal-ammoniac is chiefly employed in the preparation of caustic and carbonated ammonia, in tinning iron, copper, brass, in soldering; it is farther used in medicine, dyeing, and chemical research. Its volatility, and its power of preventing the precipitation of salts otherwise insoluble, in common with other ammoniacal salts, are the chief reasons of its use in chem. analysis.

2. *Bromide of Ammonium.* Syn. Hydrobromate or bromohydrate of ammonia. *Ger.* Bromammonium. *Prep.*, 1, by mingling the 2 gases in equal volumes; 2, by saturating liquid ammonia with bromohydric acid; 3, by dissolving bromine in ammonia, when nitrogen is evolved; an excess of bromine gives a yellow solution.

Prop. By evaporating the solution, it yields 4-sided prisms, which have a sharp, saline taste, may be sublimed; gradually becomes yellowish in the air, and tests acid.

Composition. NH₄, Br, or NH₃, HBr, or HAd, HBr.—NH₃, 17·16 + HBr, 79·4 = 96·56. In 100 pts. NH₃, 17·78 + HBr, 82·22 = 100.

3. *Iodide of Ammonium.* Syn. Hydriodate of ammonia. *Ger.* Iodammonium. *Prepared*, 1, by mixing equal volumes of the 2 gases, iodo-hydric acid and ammonia; 2, by saturating liquid iodo-hydric with caustic ammonia, and concentrating the solution; 3, by precipitating a solution of iodide of iron by carbonate of ammonia and filtering.

Prop. Crystallizes with some difficulty in cubes; colorless, deliquescent, very soluble in water and alcohol; apart from access of air, sublimes unchanged; but by access of air it gives off ammonia by oxidation and the sublimate is colored yellow by periodide; the same change occurs in its aqueous solution, which becomes yellow and contains free ammonia. Absorbs dry sulphuric acid vapor, evolving sulphurous acid and forming a reddish brown mass.

Composition. NH₄, I, or NH₃, HI, or HAd, HI.—NH₃, 17·16 + HI, 127·57 = NH₄, I, 144·73. In 100 pts. NH₃, 11·86 + HI, 88·14 = 100.

Periodide of Ammonium. *Ger.* Ammonium-iodid. Formed by saturating a concentrated solution of the iodide with iodine. A dark brown, opaque liquid.

Iodine absorbs dry ammonia, forming a peculiar compound, which is also produced by gently heating iodine with sesquicarbonate of ammonia, with the evolution of water and carbonic acid. It is a dark brown, viscid liquid, with a metallic lustre, loses part of its ammonia by heating, and then vaporizes with a violet color, readily soluble in alcohol. According to Millon, it is composed of NH₃, I; according to Bineau, 3 NH₃, 2 I; and Millon regards it as a compound of 1 eq. iodide of nitrogen (amide of iodine) + 1 eq. iodide of ammonium; thus, 2 (NH₃, I) = NH₂, I + NH₄, I. It is decomposed by water into iodide of ammonium and iodide of nitrogen, which precipitates.

4. *Fluoride of Ammonium.* Syn. Fluat or fluohydrate of ammonia. *Prepared* by heating 1 pt. very fine sal-ammoniac with 2½ pts. very fine fluoride of sodium, thoroughly mixed in a platinum crucible, with a cover curved inwards, and containing a little water; by a gentle heat the fluoride of ammonium sublimes and condenses on the lower surface of the cover. If moisture were present, some ammonia is given off, and the salt contains also acid fluoride. The dry salt cannot be obtained from its solution.

Colorless, of a biting saline taste, very soluble in water, little in alcohol; its aqueous solution changes to acid fluoride; fuses and sublimes at a lower heat than sal-ammoniac. Its solution, and even the dry salt, corrodes glass powerfully, being resolved into ammonia and silicofluoride of ammonium. For etching on glass the solution is brushed over the drawing on glass graved through wax.

A basic salt is formed by bringing the above dry fluoride into ammoniacal gas, which it absorbs with avidity, and loses again by heat.

Acid fluoride of Ammonium is formed by evaporating a solution of the fluoride at about 100°, when ½ of the ammonia escapes. A granular, crystalline mass, unchangeable in dry air at 100°, but at common temperatures very deliquescent; sublimes with white vapors. Formula of neutral fluoride, NH₄, F; of the acid salt, NH₄, F + HF.

5. *Borofluoride of Ammonium.* Syn. Fluoborate of Ammonia. *Ger.* Borfluorammonium. *Prepared* by adding boracic acid to fluoride of ammonium, by which ammonia and water are eliminated; thus, 4 (NH₄, F) + BO₃ = (NH₄, F + BF₃) + 3 NH₃ + 3 HO. By evaporation and sublimation it is separated from the excess of boracic acid; the sublimate is white, amorphous, and nearest to the heat fused and translucent. From its solution it crystallizes in 6-sided prisms, pointed by 2 planes, has a taste like sal-ammoniac, an acid reaction, very soluble in water, rather soluble in alcohol. It crystallizes again out of a strong ammoniacal solution. Its aqueous solution does not attack glass. Formula, NH₄, F + BF₃. *Berz.*

6. *Silicofluoride of Ammonium.* Syn. Fluosilicate of Ammonia. *Ger.* Kieselfluorammonium. *Prep.* Sublime an intimate mixture of fine sal-ammoniac and silicofluoride of potassium or sodium; it is a white, cohering, amorphous mass. Or add ammonia to fluosilicic acid, when a portion of silica precipitates, but redissolves by evaporation. Very soluble in water, from which it crystallizes spontaneously in 4 or 6-sided prisms; tastes very saline, reddens litmus; decrepitates by heat, and sublimes without fusion. The concentrated boiling solution attacks glass. *J. Davy.* Ammonia does not precipitate all the silica. *Berz.* Formula, NH₄, F + 2 SiF₃.

The following are compounds of ammonia

with haloids, in which the ammonia appears not to exist as oxide of ammonium; Berzelius terms them haloid salts of ammonia.

1. *a. Subchloride of Sulphur and Ammonia.* Syn. Ger. Schwefelchlorür-Ammoniak. Fr. Chlorosulfite d'ammoniaque. Bring together the vapor of subchlor-sulphur and ammonia. Permanent for some time, soluble in alcohol, from which water precipitates sulphur, leaving sal-ammoniac and hyposulphite of ammonia. Thus, $2\text{NH}_3 + \text{S}_2\text{Cl} + \text{HO} = \text{NH}_4\text{Cl} + \text{NH}_3\text{SO} + \text{S}$.

b. Chloride of Sulphur + 2 Ammonia. Syn. Ger. Chlorschwefel-Ammoniak. Fr. Chlorure de soufre bi-ammoniacal. Prep. Pass dry ammoniacal gas into a closed glass cylinder, and when full, introduce small capsules containing a few drops of chloride of sulphur, fully saturated with chlorine; it is best performed in cold weather to avoid the heating of the apparatus; the ammonia must be constantly in excess. When finished, the vessel is closed by a glass plate, and the next day air passed through to drive out the excess of ammonia. The same compound is also prepared by exposing *c* to ammonia, until an equiv. is absorbed.

Prop. Light lemon-yellow flocculæ, inodorous, sparingly soluble in absolute alcohol and ether, with a yellow color, from which it crystallizes by evaporation, accompanied by partial decomposition. Gently heated in a glass tube, yields ammonia, then nitrogen with sulphur and sal-ammoniac, while sulphuret of nitrogen constantly sublimes. Oil of vitriol extracts ammonia with violence; water readily decomposes it. Form., $2\text{NH}_3\text{SCI}$; contains 39.8 per cent. ammonia.

c. Chloride of Sulphur + 1 Ammonia. Syn. Fr. Chlorure de soufre ammoniacal. Prep. Similar to *b*, but with less ammoniacal gas.

Prop. Brownish red, loose flocculæ, of an odor resembling chloride of sulphur, of a saline, very biting taste; very soluble in absolute alcohol and ether, the solutions giving, with solutions of lead and silver, mixed precipitates of metallic chlorides and hyposulphites. Heated in a tube to 230° , for some hours, it is wholly changed into a yellow mixture of sal-ammoniac and sulpho-chloride of sulphuret of nitrogen; thus, $4(\text{NH}_3\text{SCI}) = 3\text{NH}_4\text{Cl} + \text{NS}_3\text{SCI}$. Oil of vitriol acts as on *b*; water decomposes it, and liquid ammonia more rapidly. Form., NH_3SCI ; contains 25 per cent. ammonia.

2. *Terchloride of Phosphorus + 5 Ammonia.* Syn. Phosphorsuperchlorür-Ammoniak. Berz. Pass ammonia very slowly to saturation, through terchloride of phosphorus, in a vessel surrounded by a freezing mixture. A white powder, slowly but wholly soluble in water. Heated in a stream of carbonic acid, it yields ammonia, phosphorus-vapor, phosphuret of nitrogen, and sal-ammoniac; thus, $2(5\text{NH}_3\text{PCl}_3) = 6\text{NH}_4\text{Cl} + 2\text{NH}_3 + \text{N}_2\text{P} + \text{P}$; a little hydrogen liberated, is probably accidental. It is much more stable than we might infer from its composition; fused with fixed alkaline carbonates, it yields ammonia, and alkaline phosphates, and chlorides; boiled for some time, with their solutions, it yields the same, excepting that there is an alkaline phosphite; heated nitric acid dissolves it slowly with evolution of

nitric oxide. Form., $5\text{NH}_3\text{PCl}_3$; contains 38.4 per cent. ammonia (*Rose*), 33 per cent. (*Persoz*.)

3. *Chlorocarbonate of Ammonia.* Syn. Ger. Chlorkohlenoxyd-Ammoniak, Phosgen-Ammoniak. 1 vol. chlorocarbonic acid + 4 vols. ammoniacal gas condense with evolution of heat to a white solid, inodorous, of biting saline taste, of neutral reaction, deliquescent, soluble in spt. wine; decomposed by the stronger acids; may be sublimed. Form., $2\text{NH}_3\text{COCl}$. Regnault regards it as sal-ammoniac and carbamide, $2\text{NH}_3\text{COCl} = \text{NH}_4\text{Cl} + \text{NH}_2\text{CO}$.

4. *Terchloride of Boron + Ammonia.* 1 vol. gaseous terchloride of boron and $1\frac{1}{2}$ vols. ammonia condense to a white powder; sublimes unchanged, less volatile than sal-ammoniac; decomposed by water into sal-ammoniac and borate of ammonia. Form., $\text{BCl}_3 + 3\text{NH}_3$; contains 18.36 per cent. ammonia. To decompose by water, as above, it should contain 4NH_3 ; thus, $\text{BCl}_3 + 4\text{NH}_3 + 3\text{HO} = \text{NH}_3\text{BO}_3 + 3(\text{NH}_3\text{HCl})$.

5. *Terchloride of Silicon + Ammonia.* Similar to the preceding, decomposed by water into sal-ammoniac, silicic acid and ammonia. Form., $\text{SiCl}_3 + 3\text{NH}_3$ (?); contains 37.56 per cent. ammonia.

6. *Terbromide of Phosphorus + Ammonia.* Syn. Phosphorbromür-Ammoniak. (*Berz.*) Formed similarly to the chlorine compound, which it also resembles in appearance and mode of decomposition. Form., $\text{PBr}_3 + 5\text{NH}_3$; contains 24.37 per cent. ammonia.

7. *Fluoride of Boron + Ammonia.* Equal measures of the 2 gases condense to a white, opaque solid, which may be sublimed unaltered, by a gentle heat in a close vessel, dissolves in water, forming borofluoride of ammonium and borate of ammonia. 1 vol. fluoride of boron + 2 and 3 vols. ammonia, condense to clear liquids, not easily distinguishable from each other, both losing their excess of ammonia, and becoming the 1st solid compound. Form., BF_3 , (1, 2, 3) NH_3 .

8. *Fluoride of Silicon + Ammonia.* The 2 gases condense only in the ratio of 1 vol. fluoride of silicon + 2 vols. ammonia to a white powder; sublimes without decomp. when dry; water resolves it into silico-fluoride of ammonium and silicic acid. Form., $2\text{SiF}_3 + 3\text{NH}_3$; contains 25 per cent. ammonia.

Cyanide of Ammonium, see under CYANOGEN; see also under the Fluorides of COLUMBIUM, MOLYBDENUM, TITANIUM, TUNGSTEN; farther under Terchloride of ARSENIC, &c.

OXY-SALTS OF AMMONIUM AND AMMONIA.

1. *Sulphate of Ammonia.* *a. Neutral.* Syn. Sulphate of oxide of ammonium. Lat. Sal-ammoniacum secretum Glauberi. Ger. Schwefelsaures Ammoniak. Found native, as Mascagnine, a volcanic mineral. Prep. Frequently made in the process of manufacturing sal-ammoniac (see *Chloride of Ammonium* above), and may readily be obtained by the action of sulphuric acid on sal-ammoniac or carbonate of ammonia.

Prop. Cryst. generally flat prisms, right rhombic system, resembling those of sulphate of potassa in form and measurement; the

obtuse angle of the vertical prism = $111^{\circ} 15'$, that of a horizontal prism = $121^{\circ} 8'$. Of a sharp, bitter taste, scarcely changing in the air, soluble in 2 cold and 1 boiling water; decrepitates by heat, fuses at 284° and begins to decompose at 536° , evolving ammonia, water, and nitrogen, and sublimes as sulphite, with a little sulphate of ammonia; decomposed in an ignited tube into water, sulphur, and nitrogen; evaporated with muriatic acid is resolved into sal-ammoniac and *b*.

Form., NH_4O , $\text{SO}_3 + \text{HO}$, or NH_4O , SO_3 , probably the latter from the isomorphism of NH_4O with potassa KO. Equiv. of NH_4O , SO_3 ($\text{H} = 1$) 66.28, or ($\text{O} = 100$) 828.17. In 100 pts., NH_3 , 25.89 + SO_3 , 60.53 + HO , 13.58.

b. Bisulphate. Crystal. in scales, has a very acid and bitterish taste, slowly deliquesces, soluble in 1 pt. cold water.

Double salts are obtained by saturating the bisulphate with several bases, potassa, soda, &c. Sulphate of potassa and ammonia, scaly, shining crystals of bitter taste, and permanent in air. Sulphate of soda and am. crystallizes in short prisms; saline and bitter, permanent. Form., NH_4O , NaO , $2\text{SO}_3 + 4\text{HO}$. Sulph.

Composition.	H = 1	O = 100	In 100 pts.	Rose.	Rose.
NH_3	17.16	214.5	29.78	29.29	
SO_3	40.12	501.17	70.22	70.75	70.04
	57.28	715.67	100	100.04	

Heated in the air, it evolves sulphurous acid, ammonia and the sulphite leaving bisulphate of amm. Its solution gives off its ammonia at common temperatures, when mixed with potassa, lime, or carbonate of potassa; the alcoholic solution of bichloride of platinum precipitates immediately a little more than $\frac{1}{2}$ the ammonia; racemic, tartaric, and carbazotic acids only give a precip. after some time, and it is then only partial. Nor can the sulphuric acid be separated more easily, for a soluble salt of baryta precipitates less than $\frac{1}{3}$ of the acid in the course of an hour, and even after long boiling, with the addition of muriatic or nitric acid, about $\frac{1}{2}$ is thrown down; to get all of the acid as insoluble sulphate of baryta, it is necessary to evaporate to dryness, and ignite it strongly. With chloride of strontium at common temperatures, it only gives a slight precip. after a week. This behavior shows that it is not common sulphate of ammonia in solution.

Rose and others regard it as a direct compound, NH_3 , SO_3 ; Kane views it as oil of vitriol, HO , SO_3 , in which the oxygen of the water is replaced by amide, HAD , SO_3 ; Dumas regards it as hydrous sulphamide, or sulphohydramide, NH_2 , HO , SO_2 .

b. Acid Sulphate-Ammonia. Is formed at the same time with the preceding, as a hard glassy mass, very deliquescent in the air, dissolving in water, with a hissing noise.

c. Neutral Parasulphate-Ammonia. Syn. Parasulfat-ammon, Rose. The solution of *a* by evaporation, yields *c* and *d*. Prep. Evap. the solution of *a* by a very gentle heat, and then in vacuo over oil of vitriol, and dry the crystals with filtering paper, to free them from the

lithia and am. tabular crystals, very soluble. Other double salts containing sulphate of ammonia, see under the several metals.

2. *Sulphate-Ammonia* or *Anhydrous Sulphate of Ammonia*. Dry sulphuric acid and dry ammonia unite, and form bodies, which are not salts of sulphuric acid, with oxide of ammonium. Rose.

a. Neutral Sulphate-Ammonia. Syn. Sulfatammon, Rose; Sulfamide, Dumas. Prep. Conduct dry sulphuric acid vapor into a flask, surrounded by a freezing mixture, and when it has deposited uniformly on the sides, by turning the glass round, pass in dry ammonia, which is absorbed rapidly, and with evolution of heat; the outside only is the salt in question, and is carefully scraped off from that beneath it, and should not have an acid reaction.

Prop. White, dry, amorphous powder, taste similar to common sulphate of ammonia (1); neutral, permanent in air. Soluble in about 9 pts. cold water, the solution does not change by lapse of time; soluble with difficulty in oil of vitriol, insoluble in and not altered by alcohol.

mother-liquor, which contains the following salt *d*. Or, after scraping off the salt *a* (see *a*), recharge the vessel, lined with the acid salt, with ammonia; suffer it to remain some time in contact with it, then expel the ammonia by a current of dry air; expose the vessel for some time to moist air, and dissolve slowly in water; remove the excess of sulphuric acid by shaking with carbonate of baryta, and evaporate slowly and in vacuo as before.

Prop. Cryst., hemiedric forms of the right square system, limpid. When free from *d* the salt is not deliquescent; moistened with water, and exposed to the air, it loses a little acid and becomes *d*; rather more soluble in water than *a*; the solution is neutral and appears to change to *d* very slowly in closed vessels. Dissolved in 9 pts. water it resembles *a* in its behavior to bichloride of platinum, carbazotic, tartaric, and racemic acids, and to salts of baryta, strontia, &c., excepting that as long as *d* is not present it is less easily affected by those reagents.

This salt has the same composition as *a*, Rose having found in it 70 to 70.29 per cent. sulphuric acid.

d. Deliquescent Sulphate-Ammonia. Syn. Ger. Zerfliessliches Sulfatammon. Formed from the gradual decomposition of *a* and *c*. Evaporate the solution of *a* to dryness in vacuo over oil of vitriol, expose it to the air to deliquesce, pour off the liquid formed, evaporate it to crystallize the balance of *c*, and suffer the clear solution to crystallize in vacuo.

Cryst. indistinct needles, soluble in water, exhibit a slightly acid reaction. Resembles *a* in its behavior to reagents; with chloride of barium only $\frac{1}{3}$ of the sulphuric acid is

precipitated in 24 hours at common temperatures.

According to analysis, it consists of 2 eq. ammonia, 2 eq. sulphuric acid, and 1 eq. water; Rose found 64.14 per cent. acid, which, by calculation, should be about 65. Form., 2NH_3 , 2SO_3 , HO, which may be viewed as a compound of (a) anhydrous sulphate of ammonia, with the common sulphate, $\text{NH}_3\text{SO}_3 + \text{NH}_4\text{O}$, SO_3 , but this is not likely from its reactions; or, on the sulphamide view, as the sulphosuesquihydramide: thus, 2NH_3 , 2SO_3 , HO = $2(\text{NH}_2\text{SO}_2) + 3\text{HO}$.

3. *Hyposulphate of Ammonia.* Ger. Unterschwefelsaures Am. Prepared by adding sulphate of ammonia (1) to hyposulphate of baryta, or sulphhydrate of ammonium to hyposulphate of manganese, filtering, and suffering the filtrate to evaporate spontaneously. Crystallizes with difficulty, in fine prismatic or capillary crystals, of a cooling, saline taste, permanent in air, soluble in 0.79 pts. water at 60.8° , the solution may be boiled without decomposition. Form., NH_3 , S_2O_5 , 2HO. Contains, by calculation, NH_3 , 15.98 + S_2O_5 , 67.26 + HO, 16.76 = 100. Heeren found 18.44 per cent. water.

4. *Sulphite of Ammonia.* Syn. Sulphite of Oxide of Ammonium. Ger. Schwefligsaures Ammoniak. Formed by passing sulphurous acid through ammonia. Cryst. hexagonal columns, with hexag. summits, of a cooling, sharp, sulphurous taste; soluble in 1 pt. water at 53.6° , producing much cold, more soluble in hot, the solution loses ammonia by boiling; in the air becomes soft, then hard, and is changed into sulphate; slightly decrepitates by heat, becomes soft without fusion, gives off ammonia and water, and may then be sublimed as *bisulphite* of ammonia. Form., NH_3 , HO, SO_2 , or NH_4O , SO_3 , which, calculated, gives NH_3 , 29.45 + HO, 15.44 + SO_2 , 55.11 = 100. Form. of the bisulphite, NH_4O , 2SO_2 .

5. *Bisulphite-Ammonia*, or anhydrous bisulphite of ammonia. Ger. Sulfit-Ammon. Dry sulphurous acid and ammonia gases condense only in equal volumes, to a yellowish red, soft mass, which, by keeping in the cold, crystallizes in groups of reddish yellow, radiating needles. It is deliquescent, and becomes colorless in the air, very soluble in water, with yellowish color, which becomes colorless, and tests, slightly, acid; kept in a close vessel, it deposits sulphur, its acid probably transforming into sulphuric and hyposulphurous acids. From its various reactions, it is doubtful whether to regard it as a sulphite-ammonia, or

as a mixed sulphate and hyposulphite-ammonia. Form., NH_3 , 2SO_2 . It may be viewed as a direct compound, as in the formula, or as NH_3 , SO, SO_3 , in which it resembles the common sulphate of ammonia (1), excepting that SO replaces HO. Rose conjectures that NH_3 is combined with a polymeric sulphurous acid: thus, NH_3 , S_2O_4 , which may easily be resolved by reagents into SO and SO_3 , a theory that accords well with its behavior. Equiv. ($\text{H} = 1$) = 81.4.

6. *Hyposulphite of Ammonia.* Ger. Unterschwefligsaures Ammoniak. Formed from hyposulphite of lime and carbonate of ammonia; by evap. yields a soft mass of white needles, or shining, white scales, evap. over oil of vitriol, gives rhombic laminæ, very soluble in water; easily decomposed by heat. Form., 3NH_3 , $3\text{S}_2\text{O}_3$, 4HO = $3(\text{NH}_4\text{O} \cdot \text{S}_2\text{O}_2) + \text{HO}$; contains NH_3 , 22.17 + S_2O_2 , 62.33 + HO, 15.5 = 100.

1. *Nitrate of Ammonia.* Syn. Nitrate of Oxide of Ammonium. Lat. Nitrum flammans. Ger. Salpetersaures Ammoniak. Prep. Neutralize ammonia or its carbonate by nitric acid, evaporate and set aside to crystallize.

Prop. According to the concentration, cryst. in 6-sided prisms with 6-sided pyramids, in fine needles, or even compact. It has a sharp, bitter taste, deliquescent, soluble in 0.502 pt. water at 64.4° , producing much cold, in less hot water; spec. grav. 1.707; by loss of ammonia in the air, gives acid reaction.

By a gradually increasing heat it is resolved into nitrous oxide gas and water: thus, NH_4O , $\text{NO}_3 = 2\text{NO} + 4\text{HO}$; fuses imperfectly at 133° , perfectly at 226° , boils without decomp. at 356° , begins to decompose between 374° and 392° (gives off nitrous oxide at 460° to 480° . Pleischl). When heated so high as to emit white fumes, the products are water, nitrous and nitric oxides, nitrate of ammonia and free ammonia. Thrown on an ignited porcelain plate, it burns with a pale yellow light, giving water, nitrogen, and nitrous acid; it detonates on ignited coals; phosphorus thrown into the fused salt, burns brilliantly to phosphoric acid, or, if in quantity, to oxide of phosphorus; when fused, it oxidizes most metals, zinc and lead rapidly, antimony, bismuth, nickel, copper, and silver, slowly; arsenic, tin, iron, and mercury, not at all. Fused with sal-ammoniac and a little saltpeter or chlorate of potassa, it oxidizes and dissolves even gold, platinum, rhodium, and iridium, rutile, chromic iron-ore, sulphuret of molybdenum, pitchblende, &c. Composition:

Crystal.			In 100 pts.	Eerz.	Davy.	Fibrous.
	H = 1	O = 100				Davy.
NH_3	17.16	214.5	21.36	21.143	18.4	19.3
NO_5	54.16	677	67.43	67.625	69.5	72.5
HO	9	112.5	11.21	11.232	12.1	8.2
	80.32	1004	100	100	100	100

Form., NH_4O , NO_5 . Dumas assumes 2 eq. water, NH_3 , NO_5 , 2HO.

2. *Nitrite of Ammonia.* Syn. Nitrite of Oxide of Ammonium, Hyponitrite of Ammonia. Ger. Salpetrigsaures Ammoniak. Prep. Pre-

cipitate nitrite of lead by sulphate of ammonia, or rub nitrite of silver with sal-ammoniac and water, suffer the solution to evaporate spontaneously in air or in vacuo.

Prop. A white crystalline mass, which is

resolved by heat into water, nitrous oxide and ammonia. Its aqueous solution, maintained at 122° , is wholly resolved into nitrogen and water, $\text{NH}_3, \text{NO}_3 = 2\text{N} + 3\text{HO}$. Form., $\text{NH}_4\text{O}, \text{NO}_3$; contains $\text{NH}_3, 26.68 + \text{NO}_3, 59.33 + \text{HO}, 13.99 = 100$; Berzelius found 13.68 per cent. water.

3. *Sulphite of Nitric Oxide and Ammonia*. Syn. Ger. Stickschwefelsaures Ammoniak. Fr. Nitrosulphite d'ammoniaque. Mix caustic ammonia with concentrated sulphite of ammonia, cool it down and pass nitric oxide through it; the crystals obtained are washed with ammonia. Cryst. rhombic prisms, transparent, of a pungent and slightly bitter taste; changes gradually in air to sulphate of amm., with evolution of nitrous oxide, a change which its solution soon suffers; thus, $\text{NH}_3, \text{NO}_2, \text{SO}_2 = \text{NH}_3, \text{SO}_3 + \text{NO}$; this change is very slow at 32° , rapid at 100° . The presence of charcoal, binoxide of manganese, oxide of silver, platinum sponge; the stronger acids, even carbonic, solutions of iron or copper vitriol, corrosive sublimate, nitrates of lead and silver, cause a more rapid decomposition, which is lessened by an excess of ammonia. The salt is permanent as high as 230° , at a higher heat it explodes, evolving nitrous oxide.

Form., $\text{NH}_3, \text{NO}_2, \text{SO}_2, \text{HO}$.

1. *Phosphate of Ammonia*. Syn. Tribasic Phosphate of Amm. Ger. Phosphorsaures Ammoniak. a. *Neutral*. Exists as a double salt, with phosphate of soda or magnesia, in the urine of carnivorous animals, in calculi, &c. Prep. Add ammonia to strong phosphoric acid until it reacts alkaline, when the cooling liquid deposits crystals; or, to somewhat calcareous phosphoric acid, add carbonate of ammonia, until effervescence and a precipitate of phosphate of lime ceases, filter, evaporate, adding ammonia to replace that lost during evap., so that the liquid remains alkaline, and set aside to crystallize.

Prop. Cryst. oblique-rhombic, limpid; taste cooling, saline, pungent; tests alkaline; insoluble in alcohol, soluble in 4 pts. cold, less hot water, the solution loses a portion of ammonia, becoming b; effloresces slightly in the air, losing some ammonia at ordinary temperatures; fuses by heat, losing water and ammonia, and becoming dry, and finally, by ignition, gradually becomes fused hydrated phosphoric acid. Form., $2\text{NH}_4\text{O}, \text{HO}, \text{PO}_5$ (or $2\text{NH}_3, \text{PO}_5, 3\text{HO}$); contains $\text{NH}_3, 26.02 + \text{PO}_5, 53.69 + \text{HO}, 20.29 = 100$; Mitscherlich found 54.426 per cent. phosphoric acid.

b. *Acid*. Add phosphoric acid to ammonia, until it tests strongly acid, and does not precipitate chloride of barium. Cryst. right-rhombic, taste and test acid, soluble in 5 pts. cold and less hot water; loses ammonia by heat, like a. Form., $\text{NH}_4\text{O}, 2\text{HO}, \text{PO}_5$ (or $\text{NH}_3, \text{PO}_5, 3\text{HO}$); Mitscherlich found 61.02 per cent. phosphoric acid, which is a little less than it should contain.

2. *Pyrophosphate of Ammonia*. Syn. Bibasic Phosphate of Amm. Exists only in solution, for upon evaporation, it takes up an equivalent of water, and becomes 1., a. Formula, $2\text{NH}_4\text{O}, \text{PO}_5$.

3. *Metaphosphate of Ammonia*. Syn. Mono-

basic Phosphate of Amm. Also known only in solution, which, by spontaneous evaporation, crystallizes as 1. b. Form., $\text{NH}_4\text{O}, \text{PO}_5$.

4. *Phosphite of Ammonia*. Ger. Phosphorigsaures Ammoniak. Neutralize phosphorous acid by ammonia, and evaporate to a syrup; crystallizes in large 4-sided prisms, with octahedral terminations, deliquescent, soluble in 2 pts. cold, less hot water; by heat loses ammonia, becoming phosphorous acid, with 3 HO, which, by farther heat, is resolved into phosphuretted hydrogen and phosphoric acid. Form., $2\text{HN}_3\text{O}, \text{PO}_3$.

5. *Hypophosphite of Ammonia*. Ger. Unterphosphorigsaures Amm. Deliquescent, soluble in water and absolute alcohol; loses ammonia by heat, becoming hydrous hypophosphorous acid, which is farther decomposed by heat into phosphorus, phosphoric acid, and phosphur. hydrogen. Form. $\text{NH}_4\text{O}, \text{PO}$.

Phosphate of ammonia forms several important double salts, which will be found under phosphate of soda, magnesia, &c.

1. *Perchlorate of Ammonia*. Ger. Ueberchlorsaures Amm. Transparent, right-rhombic prisms, soluble in 5 pts. cold water, slightly in alcohol; neutral, until evaporated, when it loses ammonia and tests acid; it is precip. by concentrated perchloric acid. Form., $\text{NH}_4\text{O}, \text{ClO}_7$.

2. *Chlorate of Ammonia*. Ger. Chlorsaures Amm. Prepared, either by mixing ammonia, or its carbonate, with chloric acid, or by precipitating chlorate of baryta, strontia, or lime, by carbonate of ammonia, or, according to Berzelius, by adding to a solution of silicofluoride of ammonium, finely powdered chlorate of potassa, in small portions, as long as silicofluoride of potassium falls down; evaporate at a gentle heat.

Prop. Cryst. in fine needles; taste sharp; very soluble in water and alcohol; volatilizes below 212° , at a little higher temperature gives off chlorine, nitrogen, and nitrous oxide; thrown on a strongly heated body, it explodes, with a red light; Mitscherlich says it may explode spontaneously. Form., $\text{NH}_4\text{O}, \text{ClO}_5$.

Iodate of Ammonia. Neutralize iodic acid or terchloride of iodine, with caustic or carbonated ammonia. A subsoluble powder; by slowly evaporating its solution, it crystallizes in brilliant, colorless cubes; soluble in 38.5 water at 59° , in 6.9 boiling. Heated to 300° , decomposes, with rapidity, into vapor of iodine, water, and into nitrogen and oxygen in equal volumes; thus, $\text{NH}_4\text{O}, \text{IO}_5 = \text{I} + 4\text{HO} + \text{N} + 2\text{O}$; deflagrates violently on ignited coal, with a violet color; decomposed by strong chlorohydric acid into water, chlorine, and a compound of sal-ammoniac, with terchloride of iodine. Form., $\text{NH}_4\text{O}, \text{IO}_5$.

Bromate of Ammonia. Prep. by neutralizing bromic acid with ammonia, or by precipitating bromate of baryta by carbonate of ammonia. By evap. yields fine needles or granular crystals, colorless, of a sharp and cooling taste, soluble in water. Explodes in a short time spontaneously, even at common temperatures, yielding bromine vapor, water, nitrogen, and oxygen (see under the preceding salt). Form., $\text{NH}_4\text{O}, \text{BrO}_5$.

1. *Carbonate-Ammonia*. Syn. Anhydrous Carbonate of Amm., Carbohydramide (?). *Ger.* Kohlensaures Ammon. Dry carbonic acid and ammonia slowly unite, evolving heat, only in the proportion of 1 vol. $\text{CO}_2 + 2$ vols. NH_3 . The salt may be made by passing the dry gases through several tubes cooled very low, or, by subliming a mixture of dry sulphate-ammonia and dry carbonate of soda. It is a white mass, giving off the odor of ammonia, with alkaline reaction, vaporizes above 140° , may be repeatedly sublimed without change. Dry chlorine decomposes it, after some days, into sal-ammoniac, carbonic acid, and nitrogen; dry sulphuric acid forms sulphate-ammonia; heated in sulphurous acid, it sublimes sulphite-ammonia. Its solution acts like the following salt. Form., $\text{NH}_3, \text{CO}_2 (\text{NH}_2, \text{HO}, \text{CO} ?)$; it contains NH_3 , $43.82 + \text{CO}_2$, $56.18 = 100$; Rose found NH_3 , $44.69 + \text{CO}_2$, $55.45 = 100.14$.

2. *Carbonate of Ammonia, Neutral*. Syn. Carbonate of Oxide of Ammonium. *Ger.* Einfach Kohlensaures Ammoniak. Heat gently in a retort, common sesqui-carbonate of amm., or a mixture of sal-ammoniac and carbonate of soda; carbonic acid first escapes from the beak of the retort dipping under mercury, when the neutral carbonate sublimes, and is subsequently followed by other salts.

Prop. White crystalline, may be repeatedly sublimed without change; deliquescent, very soluble in water, and cannot be again obtained from solution, which readily parts with a portion of ammonia. Its very dilute solution precipitates chloride of calcium after some time, which distinguishes it from other carbonates. Form., $2 \text{NH}_3, \text{HO}, 2 \text{CO}_2$, which may be regarded as a compound of 1 and 2, $\text{NH}_3, \text{CO}_2 + \text{NH}_4\text{O}, \text{CO}_2$. Rose found NH_3 , $39.27 + \text{CO}_2$, $50.09 + \text{HO}$, $10.64 = 100$.

3. *Sesquicarbonate of Ammonia*. Syn. Smelling Salt, Volatile Salt of Hartshorn. *Lat.* Sal-volatile (Cornu Cervi). *Ger.* Aenderthalbkohlensaures Ammoniak, Flüchtiges Hirschhornsalz.

Prep. It is the crude saline product of the dry distillation of bones, blood, horn, &c., and is often thus procured in a solid, crystalline, but impure state. (See MANUFACTURE OF SAL-AMMONIAC above). It is usually obtained by the double decomposition of muriate or sulphate of ammonia and carbonate of lime. Mix

1 pt. sal-ammoniac (or sulphate of amm.) with $1\frac{1}{2}$ to 2 pts. powdered chalk, introduce the mixture into an earthen or cast-iron retort, and heat gradually to redness. The vapors of carbonate of ammonia are condensed in a receiver of stone-ware, lead, or glass. It is purified by resublimation in stone-ware or glass, which, when sufficiently full, is broken, and the solid white, crystalline cake thrown into market.

The double decomposition is simple, chloride of ammonium and carbonate of lime, yielding carbonate of ammonia and chloride of calcium, while water and ammonia escape; thus, $3 (\text{CaO}, \text{CO}_2) + 3 \text{NH}_4\text{Cl} = 3 \text{CaCl} + 2 \text{NH}_4\text{O}, 3 \text{CO}_2 + \text{NH}_3 + \text{HO}$.

Impurities. It may contain hyposulphite (from sulphate), sulphate, or muriate of ammonia, which may be detected, as shown under those acids; lime, or chloride of calcium, may also be present, which can be ascertained by vaporizing a portion of the salt, when these, or other fixed matters, remain.

Prop. White, crystalline (Ure says, when carefully sublimed, it forms rhombic octahedra), has an ammoniacal odor, sharp taste, alkaline reaction. It is soluble in water, 1 pt. dissolving in 4 pts. water at 55° , in 3.3 at 62° , in 2.7 at 90° , in 2.4 at 105° , and in 2 at 120° . But it is readily decomposed by solution in water. From its warm, saturated solution, bicarbonate of ammonia crystallizes on cooling, or is precipitated by alcohol. A smaller quantity of water than is necessary for solution, extracts chiefly neutral carbonate, and leaves the bicarbonate. The complete solution heated, evolves carbonic acid and a little ammonia, until the neutral salt remains. Dry sulphuric acid vapor conducted over it, resolves it into sal-ammoniac and hydrous sulphate of ammonia; sulphurous acid, with heat, produces first, sulphite-ammonia, then hydrous sulphite of ammonia. It effloresces in the air to a white pulverizable mass of bicarbonate. When heated, it begins at 120° to evolve carbonic acid, then neutral carbonate (2), mixed more and more with sesquicarbonate (3); after 2, there sublimes the following salt (4), and finally the clear liquid in the retort deposits, on cooling, crystals of sesquicarbonate, with 5 eq. water (3. b.), while the solution contains neutral carbonate (2).

Calculated composition.

2NH_3	34.32	29.01	24
3CO_2	66	55.79	52
2HO	18	15.20	24
	118.32	100.00	100

<i>Kirwan.</i>	<i>J. Davy.</i>	<i>H. Rose.</i>	<i>H. R.</i>	<i>H. R.</i>
24	27.39	28.66	30.7	
52	54.58	50.55	53.4	56.23
24	18.03	20.79	15.9	
100	100	100	100	

The commercial salt is generally a mixture of several salts. Formula of the pure salt, $2 \text{NH}_4\text{O} + 3 \text{CO}_2$, ($= 2 \text{NH}_3, 2 \text{HO}, 3 \text{CO}_2$), which is viewed by Rose as a compound of NH_3, CO_2 and $\text{NH}_3, 2 \text{HO}, 2 \text{CO}_2$.

b. The salt mentioned above as crystallizing from the heated and fused sesquicarbonate, has the form of thin hexagonal laminæ, which gradually change in the air to bicarbonate. Formula, $2 \text{NH}_3, 3 \text{CO}_2, 5 \text{HO}$; contains, from

Rose's analysis, NH_3 , $23.56 + \text{CO}_2$, $45.55 + \text{HO}$, $30.89 = 100$.

4. The sesquicarbonate yields, by heat, 3 carbonates, containing 4 eq. amm. and 5 eq. carbonic acid. a. Sublimes as a crystalline crust, in the upper part of the retort, in which the common sesquicarbonate (3. a.) is slowly heated. Form., $4 \text{NH}_3, 5 \text{CO}_2, 4 \text{HO}$, which, according to Rose, may be viewed as $3 (\text{NH}_3, \text{CO}_2) + \text{NH}_4\text{O}, 2 \text{CO}_2 + 3 \text{HO}$; according to Gmelin,

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2 (NH₄O, CO₂) + 2 NH₄O, 3 CO₂.—*b.* Sublime sesquicarbonate (3. *b.*), or heat the preceding salt (4. *a.*) in a retort, until fused to a clear liquid; *b* sublimes, while the fused residue congeals to *c.* Form. of *b*, 4 NH₃, 5 CO₂ + 5 HO; form. of *c*, 4 NH₃, 5 CO₂ + 12 HO.

<i>a.</i>	H = 1	<i>H. Rose.</i>	<i>b.</i>	H = 1	<i>H. Rose.</i>	<i>c.</i>	H = 1	<i>H. Rose.</i>
4 NH ₃	68·64	31·13	4 NH ₃	68·64	30·53	4 NH ₃	68·64	22·70
5 CO ₂	110	52·92	5 CO ₂	110	48·56	5 CO ₂	110	38·31
4 HO	36	15·95	5 HO	45	20·91	12 HO	108	38·99
	274·64	100		223·64	100		286·64	100

5. *Bicarbonate of Ammonia.* *Ger.* Zweifach Kohlensaures Ammoniak. *a.* with 2 eq. water. Formed crystallized only by evap. of a solution of neutral carbonate (2) in vacuo, or crystalline by the evap. of sesquicarbonate in vacuo over oil of vitriol, potassa, lime, or chloride of calcium, or by saturating dissolved sesquicarbonate with carbonic acid, or precipitating the same salt by alcohol. In short, the other carbonates have a strong tendency

to pass into this salt; a bottle of common carbonate, badly corked, becomes this bicarbonate.

Cryst. oblique-rhombic system, the same as bicarb. of potassa; inodorous, has a feeble taste, an alkaline reaction, volatilizes more slowly in the air than the neutral salt; dissolves in 6 pts. water at 55°, with more salt, it evolves carbonic acid freely at 102°, and the liquid has an ammoniacal odor.

<i>a.</i> Calculated.		<i>Phillips.</i>	<i>J. Davy.</i>	<i>H. Rose.</i>	<i>H. R.</i>	<i>H. R.</i>	<i>H. R.</i>
NH ₃	17·16	21·68	21·16	21·56	21·39	21·24	21·60
2 CO ₂	44	55·58	55·50	56·01	56·09	55·42	55·88
2 HO	18	22·74	23·34	22·43	22·52	23·34	22·93
	79·16	100	100	100	100	100	100

Form., NH₃, 2 CO₂, 2 HO, which may be regarded as NH₄O, CO₂ + HO, CO₂.—*b.* With 2½ eq. water. Pour over sesquicarbonate, enclosed in a strong bottle, a quantity of boiling water sufficient for solution, close the vessel to retain the carbonic acid; on cooling, the salt crystallizes. Large limpid crystals, with brilliant surfaces, of right-rhombic system; properties the same as the preceding (5. *a.*), except the amount of solubility.—*c.* With 3 eq. water. Sublimes by heating 4. *b.* Properties same as 5. *a.*, except the amount of solubility.

Calculated.		<i>H. Rose.</i>
4 NH ₃	68·64	19·41
7 CO ₂	154	47·70
12 HO	108	32·89
	330·64	100

7. When the solution of sesquicarbonate is slowly evaporated in vacuo over oil of vitriol, so as to avoid ebullition, another carbonate separates in small crystals, which rapidly pass into 5. *a.* by loss of carbonic acid.

Calculated.		<i>H. Rose.</i>
4 NH ₃	68·64	19·12
9 CO ₂	198	55·83
10 HO	90	25·05
	356·64	100

<i>b.</i> Calculated.		<i>H. Rose.</i>	<i>Berthollet.</i>
2 NH ₃	34·32	20·02	20
4 CO ₂	88	52·89	55
5 HO	45	27·09	25
	167·32	100	100

<i>c.</i> Calculated.		<i>H. Rose.</i>	
NH ₃	17·16	19·46	18·12
2 CO ₂	44	49·91	50·67
3 HO	27	30·63	31·21
	88·16	100	100

6. Another carbonate is produced by heating the last salt (5. *c.*).

Calculated.			
NH ₃	17·16	7·81	
4 BO ₃	139·6	63·52	
7 HO	63	28·67	
	219·76	100	

1. *Quadroborate of Ammonia.* *Ger.* Zweifach-borsaures Ammoniak, *Berz.*; Vierfach-boraxsaures Am., *Gmelin.* *Prep.*, by saturating warmed caustic ammonia by boracic acid, and slowly cooling, it separates in clear, irregular, 6-sided prisms of the right-rhombic system, terminated by the octahedron and horizontal prism; at first tasteless, then burning and bitter, has an alkaline reaction; permanent in the air, soluble in about 8 pts. water, the solution loses ammonia by boiling; fuses when heated, swells up and becomes, finally, glacial boracic acid.

<i>Gmelin.</i>	<i>Arfvedson.</i>	<i>Soubeyran.</i>
5·9	7·9	7·24
63·4	64·0	55·80
30·7	28·1	36·96
100	100	100

2. *Biborate of Ammonia.* *Ger.* Neutrales borsaures Amm., *Berz.*; Doppelt b. Amm., *Gmelin.* Prepared like the preceding, but with an excess of ammonia; the temperature rises. On cool-

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ing, it deposits right-rhombic octahedra, less acute than sulphur, with terminal planes, and sometimes a more obtuse octahedron. Taste and reaction alkaline, efflorescent, changing

Calculated.		
NH ₃	17·16	13·0
2 BO ₃	69·8	52·9
5 HO	45	34·1
	131·96	100

It is evident that Arfvedson's was a different compound.

3. Another *hyperneutral borate* is formed by dissolving the preceding (2) in a close vessel in warm concentrated ammonia, when it crystallizes on cooling; or by exposing 100 crystallized boracic acid to ammoniacal gas, of which 21 will be absorbed.

Calculated.		Arfvedson.
3 NH ₃	51·48	21·55
4 BO ₃	139·6	55·95
6 HO	54	22·50
	245·08	100

Berzelius terms 1 baborate and gives for it the formula, NH₄O, 2 BO₃ + HO, 2 BO₃ + 5 HO (he gives 6 eq. water of crystal.); he terms 2 neutral, giving the formula, NH₄O, BO₃ + HO, BO₃ + 3 HO (he gives 2 eq. crystal-water); the last salt, 3, he terms $\frac{1}{2}$ basic borate, advancing the formula 3 NH₄O, 2 BO₃ + 2 (HO, BO₃) + HO.

Silicate of Ammonia. Pure caustic ammonia dissolves a considerable quantity of freshly precipitated silica.

SULPHURETS AND SULPHO-SALTS.

1. *Sulphuret of Ammonium.* Syn. Hydrosulphuret of Ammonia. Ger. Einfach Schwefelammonium, oder Einfach-Hydrothion-Ammoniak. Pass a mixture of 1 vol. sulphuretted hydrogen and a little more than 2 vols. ammonia through a tube cooled to 0°; at common temperatures they unite in equal volumes to form sulphohydrate of amm.; or, it may be obtained in solution by dividing liquid ammonia into 2 parts, saturating 1 with sulphuretted hydrogen and then adding the other part, NH₄S, HS + NH₃ = 2 NH₄S. In the former case, the gases deposit colorless crystals, with a strong alkaline reaction, losing $\frac{1}{2}$ of its ammonia immediately, at common temperatures; the liquid smells stronger of ammonia than of sulphuretted hydrogen, and readily decomposes in the air. Form., NH₄S, or NH₃, HS; contains about 50 per cent. of each constituent.

2. *5-fold Sulphuret of Ammonium.* Ger. 5-fach Schwefelammonium, Berz.; Hydrothioniges Ammoniak, Gmelin. Saturate caustic ammonia with sulphuretted hydrogen, add flowers of sulphur, while ammoniacal gas is passed through, saturate the excess of ammonia again by sulphuret. hydrog.; treat the liquid again with sulphur and gaseous ammonia; and lastly, with sulphuretted hydrogen; the cooled liquid then congeals to a crystalline mass;

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into the preceding salt (1) by loss of ammonia; soluble in about 12 pts. cold water; its solution evolves ammonia by heat. Gmelin.

Gmelin.	Soubeiran.	Arfvedson.
12·5	13·544	12·88
51	50·000	63·34
36·5	36·452	23·78
	99·996	100

fuse it at 100° to 120°, and suffer it to cool slowly in a closed vessel.

Prop. Long, orange-colored oblique-rhombic prisms; soluble in water, with the separation of sulphur; at first, perfectly soluble in alcohol, but sometimes precipitates sulphur in a crystalline state, even in closed vessels. The solution obtained by saturating sulphohydrate of ammonia by sulphur, is a dark-yellow oily liquid. The crystals gradually change in the air, giving off sulphuretted hydrogen, into a mixture of sulphur and hyposulphite of ammonia; when heated they give off sulph. hydrogen, and pass into 7-fold sulphuret (3); they suffer a similar change when kept in a large vessel, filled with dry air; 3 (NH₄, S₅) = 2 (NH₄, S₇) + NH₄S. Form., NH₄, S₅, or NH₃, HS, S₄; contains, according to Fritzsche's analysis, NH₃, 17·12 + HS, 16·115 + S, 64·7 = 97·935.

3. *7-fold Sulphuret of Ammonium.* Ger. Unterhydrothioniges Ammoniak, Gmelin. Produced by the spontaneous decomposition of the preceding (2); or the crystals of 2 are fused in their mother-liquor, and the vessel containing them placed under a large bell-glass to cool, when sulphuret of ammonium (1) volatilizes, and the 3 first crystallizes out, then 2, and lastly, 3 again. The crystals are ruby-red, soluble, and keep rather better than 2; by heat, a lower sulphuret volatilizes, which deposits in yellow drops, from which heat separates very volatile crystals, probably sulphohydrate; a low temperature, a little above that of the fusing point of sulphur, decomposes them entirely, and fused sulphur remains. Form., NH₄, S₇, or NH₃, HS, S₆; contains, according to Fritzsche, NH₃, 13 + HS, 12·92 + S, 75·09 = 101·01.

4. *Sulphohydrate of Ammonium.* Syn. Bihydrosulphuret of Ammonia. Ger. Ammonium-Sulphhydrat, Berz.; Zweifach-Hydrothion-Ammoniak, Gmelin; Schwefelwasserstoffammoniak. A salt, in which protosulphuret of ammonium is the base, and sulphuretted hydrogen (sulphohydric acid) is the acid. At common and higher temperatures, ammonia and sulphuretted hydrogen unite only in equal volumes; to obtain the salt crystallized, let the two gases meet in a vessel, cooled by ice, and filled with hydrogen or ammonia. Crystallizes in colorless needles or leaves, has an alkaline reaction, smells strongly of ammonia and sulphuretted hydrogen, volatilizes at common temperatures; changes, in air, to a higher sulphuret. A solution of this salt is made for chemical purposes, by passing sulphuretted hydrogen through caustic ammonia to saturation, with as little access of air as possible.

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Form., $\text{NH}_4\text{S} + \text{HS}$, or $\text{NH}_3, 2\text{HS}$; contains about $\frac{1}{3}$ ammonia and $\frac{2}{3}$ sulphohydric acid.

Use. This salt is largely employed, as an invaluable reagent in analytic chemistry, and is prepared for ordinary use by passing a tube, from a sulphohydrogen generating bottle, into a stoppered bottle containing ammonia, thrusting a little cotton into the mouth to avoid the influence of the air, as far as practicable. It should be fully saturated by sulphohydrogen, or otherwise the excess of ammonia interferes in the color of precipitates and is apt to mislead in research. The fresh solution is colorless, if the air has been duly excluded, but is usually tinged slightly yellow from the first, and becomes more so by standing in a loosely stoppered bottle, or when the bottle has been frequently opened, from the formation of higher sulphuret; this, however, is, in most cases, of little or no injury. When farther decomposed, it is resolved into hyposulphite of ammonia; as soon as sulphur begins to deposit, it is a useless reagent. Its use, as a reagent, depends on its power of precipitating sulphurets of nearly all the metals, which are sometimes distinguished by their color, and on its capability of dissolving the sulphurets of tin, antimony, and arsenic, by the formation of soluble sulpho-salts.

1. *Sulphocarbonate-Ammonia.* *Ger.* Schwefelkohlenstoff-Ammoniak, *Berz.* Bisulphuret of carbon slowly absorbs ammoniacal gas, forming an amorphous solid, of a faint yellow color, may be sublimed as long as it is dry; it is also formed by heating xanthate of ammonia; it attracts water strongly, becoming first, and immediately, orange-yellow, from the formation of sulpho-carbonate of ammonium (2), then lemon-yellow, being resolved into ammonia, sulphohydrogen, and water.

2. *Sulphocarbonate of Ammonium.* *Ger.* Ammonium-Sulfocarbonat, *Berz.*; Hydrothiocarbon-Ammoniak, *Gmelin.* *Formation.* Ammonia and sulphuret of carbon are resolved in carbonate and sulphocarbonate: thus, $3\text{NH}_4\text{O} + 3\text{CS}_2 = \text{NH}_4\text{O}, \text{CO}_2 + 2(\text{NH}_4\text{S}, \text{CS}_2)$. *Prep.* Mix 10 vols. of nearly absolute alcohol, saturated with ammoniacal gas, with 1 vol. of bisulphuret of carbon, fill a flask with it and close it, when the liquid has assumed a brown color, place it for an hour in ice-cold water; the salt separates partly in fine feathery crystals, partly as a crystalline powder; pour off the mother-liquor, or strain it through linen, wash the salt several times with cold and strong alcohol, then with ether, press it at once,

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and strongly, between paper, and fill a well-stoppered bottle with the dry salt.

Prop. Pale, yellow crystals, which entirely volatilize in the air in a few days, and may be sublimed when dry with little or no decomposition, even when mixed with dry carbonate of potassa; deliquescent, very soluble in water, slightly in alcohol, still less in ether; dissolved in 8 pts. water, the solution is red, in more water brownish, and in still more yellow; the solution may be kept for a long time in vessels filled with it, and well closed; in an open vessel it deposits a gray powder, containing carbon, without forming sulphocyanic acid. By the action of the moisture of the air, the salt passes from yellow into red, whence Zeise termed it Reddening salt, to distinguish it from the preceding compound (1); moistened with alcohol, it becomes red in a few seconds, when washed with ether it retains its yellow color several minutes in the air. A solution of potassa, mixed with the salt and distilled to dryness, becomes sulphocyanide of potassium. Moderately dilute chlorohydric or sulphuric acid separate sulpho-carbohydric acid, without evolving sulphohydric acid as the concentrated acids do. Empirical formula, NH_4CS_3 ; rational formula, $\text{NH}_4\text{S}, \text{CS}_2$, or $\text{NH}_3, \text{HS}, \text{CS}_2$.

Farther compounds of ammonia, see under the various metals, organic acids, &c.

AMMONIURET. *Chem.* A term sometimes applied to basic double salts of ammonia; thus, sulphate or nitrate of copper, redissolved in an excess of ammonia, form deep blue crystallizable solutions. These salts are also termed ammonio-sulphate or nitrate of copper. See COPPER.

AMNIC FLUID. *Anat.* That of man, according to Fromherz and Gugert, is yellow, cloudy, and contains 3 per cent. residue; it has an ammoniacal, alkaline reaction, is coagulated by boiling, or by alcohol, is precipitated strongly by nitric and muriatic acids, slightly by acetic, still less by potassa. Chloride of mercury gives a strong precipitate, which becomes rose-red in a few minutes; it contains free ammonia, sulphuret of ammonium, lime, and phosphate of lime held in solution by an animal substance, osmazome, casein, salivary matter, albumen, benzoic acid and urea, muriate, phosphate, carbonate, and sulphate of soda, sulphate of lime, and traces of salts of potassa. Voigt analyzed the amnic fluid of the 4th and 6th month, with different results from the preceding, which may, in part, be due to its change up to the time of birth; he found in 1000 parts:

	4th month	6th month.
Alcoholic extract and lactate of soda.....	3.69	0.34
Albumen	10.77	6.67
Chloride of sodium.....	5.95	2.40
Sulphate and phosphate of lime (including loss).....	0.14	0.30
Water.....	979.45	990.29
	1000	1000

He could not detect casein, salivary matter, urea, benzoic or hippuric acid, carbonate or sulphuret of ammonium.

Voigt analyzed the amnic fluid of a mare,

in the 3d month, which was yellow, clear, of saline taste, neutral; evaporated at 230° , left 1.45 per cent. residue, the $\frac{1}{2}$ of which was soluble in alcohol, and this solution contained no

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urea; the residue consisted of albumen 0.124, chloride of sodium 0.531, sulphate of lime 0.011.

Prout examined the amnic fluid of a cow, in an early period of gestation; it was yellowish, clouded with small floating particles, neutral, coagulated by boiling, which was not prevented by acetic acid, thus proving the presence of albumen and not casein. 100 pts. yielded:

Water.....	97.70
Albumen.....	0.26
Alcoholic extract and Lactates....	1.66
Aqueous extract, with Sugar of Milk and Salts.....	0.38

100

According to Lassaigne, the caseous floculæ floating in the amnic fluid of the cow consist of albumen combined with 0.27 of its weight of oxalate of lime.

AMNIOTIC ACID. *Chem.* Vauquelin and Buniva examined the amnic fluid of a cow, which Dzondi proved to have been a mixture of the amnic and allantoic fluids, and that the peculiar acid, which they termed amniotic, was contained in the allantoic fluid. See **ALLANTOIC ACID**.

AMOMUM. *Bot.* A genus of plants of the Zingiberacæ, which has been subdivided, and includes several useful species, Cardamoms, Grana-Paradisi, &c. For their chemical characters refer to **CARDAMOM**, **GINGER**, &c.

AMORPHOUS. From *ἀ*, without, and *μορφή*, form; bodies devoid of a regular form. It is frequently employed in mineralogy, and sometimes in chemistry, in the description of a solid, which is neither crystalline nor imitative.

Bodies seem to possess some properties slightly differing in their amorphous and crystalline state. Wöhler drew attention to this fact, in examining the fusing point of Lithofellic acid; the crystallized fused at 401°, and after congealing to an uncrystallized or amorphous state, its fusing point was from 221° to 230°. He farther observed that other substances exhibited the same peculiarity when, after fusion, they become amorphous.

	Fusing Point of the Crystalline.	Fusing Point of the Amorphous.
Sugar.....	320°	194° to 212°
Amygdalin	392°	257° — 266°
Silvic acid.....	284°	194° — 212°
Lithofellic acid	401°	221° — 230°

He draws hence the conclusion that dimorphous bodies have different points of fusion. Wöhler in *Pogg. Ann.* liv. 255.

Pelouze, in a late essay on hypochlorous acid, &c., observes that there is some difference in the chemical properties of a body in a crystalline and amorphous state, that crystalline red oxide of mercury withstands the action of chlorine, or of heat, a much longer time than the precipitated oxide; that the decomposition of crystallized binoxide of manganese is more difficult than the amorphous binoxide, and Iceland-spar more than chalk. Gay-Lussac, however, denies the correctness of Pelouze's experiments and conclusions, and yet among

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the examples which he cites, such as the equal facility of combustion of the diamond and charcoal, we would be inclined to believe that Pelouze's views were not erroneous. *Jour. f. prak. Chem.* xxviii. 351, 362.

When sulphur is heated to 320° and poured into water, it is neither crystalline nor hard when cold, but flexible, and capable of being drawn out into fine flexible threads. Rose observed that when glassy or amorphous arsenious acid passed into the crystalline state, that there was an evolution of light. Magnus observed that the mineral Vesuvian of spec. grav. 3.4, gave a glass by fusion with a spec. grav. = 2.975; that a green garnet of spec. grav. 3.63 had after fusion that of 2.95.

AMPHIBOLE. *Min.* See **HORNBLÉNDE**.

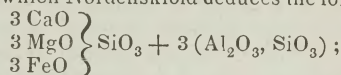
AMPHIDE-SALTS, AMPHIGEN. *Chem.* A term given by Berzelius to those salts which have one of the 4 amphigens both in the acid and base, and designed to distinguish them by one word from haloid salts. The 4 amphigen bodies are oxygen, sulphur, selenium, and tellurium. As examples of these salts, take arsenite of potassa, KO, AsO₃, sulpharsenite of potassium, KS, AsS₃, &c., which are ternary compounds, that is, composed of 3 elements, while the haloid salts consist of 2, such as chloride of sodium (common salt), NaCl. See **HALOID**.

AMPHIGENE. *Min.* See **LEUCITE**.

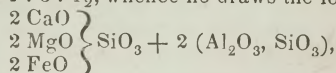
AMPHODELITE. *Min.* Cryst. has some analogy with that of felspar. H = 4.5. G = 2.763. Color light reddish, resembling scapolite in fracture, with 2 cleavages, forming an angle = 94° 19'. Nordenskiöld described and analysed it from Finland; subsequently Tennant, from Brytown, Upper Canada.

	Nordensk.	Tennant.
Silica	45.80	45.80
Alumina	35.45	26.15
Lime.....	10.15	16.25
Magnesia	5.05	2.95
Prot. of iron.....	1.70	4.70
Moisture and loss.....	1.85	2.00
	100	97.85

From which Nordenskiöld deduces the formula,



but Rammelsberg shows that the proportion of oxygen in the protobases, alumina and silica, are as 1 : 3 : 4½, whence he draws the formula,



which agrees with that of Nepheline and Elæolite, excepting that the protobases in these are potassa and soda. Tennant probably examined a mixture. The Finland specimen was from the limestone quarry of Lojo.

AMYGDALATES. *Chem.* Salts of amygdalic acid.

AMYGDALIC ACID. *Chem.* Obtained by the action of alkalis on

AMYGDALIN. *Chem.* One of the principles found in bitter almonds (see **ALMOND**), and in the berry of the cherry-laurel (*Prunus*

AMYGDALIN.

Laurocerasus). Discovered by Robiquet and Boutron-Charlard, and farther investigated by Wöhler and Liebig.

Prep. Press finely powdered bitter almonds between warm iron plates to remove the fixed oil, boil the residue several times with alcohol of 94 or 93 per cent., straining the liquid, and pressing the residue; mix the several decoctions, distil off the alcohol in a water-bath, dilute the syrupy liquid with water, add a little yeast, and set it in a warm situation to ferment; when fermentation ceases, filter, evaporate in a water-bath to a syrup, and add alcohol of 94 per cent.; this precipitates nearly all the amygdalin as a white, crystalline powder. To obtain it pure, it is pressed between paper, redissolved in boiling alcohol, and recrystallized; by exposure to the air, the adhering alcohol disappears.

Amygdalin exists, ready formed, in bitter almonds, but water cannot be employed to extract it, from its total decomposition by water and *emulsin*, another principle in the almond; hence the use of alcohol. But the alcohol extracts sugar at the same time, which impedes the crystallization of the amygdalin; this is destroyed by fermentation. 3—4 per cent. of amygdalin may be obtained.

Prop. Crystallizes in short, colorless, silky needles or scales; inodorous, taste slightly bitter, like bitter-almonds; decomposed by a high temperature, with an odor of hawthorn blossom, or like burned sugar and bitter almonds, swelling up, giving off ammoniacal products, and leaving a bulky charcoal. Scarcely soluble in cold absolute alcohol, somewhat in boiling, it is better dissolved by alcohol of 93—94 per cent., which, after cooling, retains in solution about $\frac{1}{240}$ of its weight. Very soluble in water, with which it forms a hydrate. (See below.) Dry chlorine does not act on it, but in the moist gas it is converted into a white powder, insoluble in water and alcohol, which has not been farther examined. Heated with dilute nitric acid, or with binoxide of manganese and sulphuric acid, it produces ammonia, benzoic acid, oil of bitter almonds (hydruret of benzoyl), formic and carbonic acids. By warming its solution with hypermanganate of potassa, it is instantly decolorized with the precipitation of hydrated binoxide of manganese, while benzoate and cyanate of potassa remain in solution. It is decomposed, by boiling with caustic potassa, into ammonia and amygdalic acid. (See below.) See the close of the present article for the peculiar decomposition of amygdalin by *emulsin*. Its analysis, by Wöhler and Liebig, give, in 100 pts.:

	Experiment.	Equivs.	Calcul.
Carbon.....	52·827	40	52·976
Hydrogen	5·900	27	5·835
Nitrogen	3·069	1	3·069
Oxygen	38·204	22	38·135

Formula, $C_{40}H_{27}NO_{22}$; equiv. ($H=1$) 457·16, ($O=100$) 5746·3.

Hydrates of Amygdalin. Water at 104° , saturated with amygdalin, yields, on cooling, large transparent prisms, containing 10·47 per cent., or 6 eq. water; form., $C_{40}H_{27}NO_{22} + 6 HO$.

AMYGDALIN.

When placed under a vessel, with oil of vitriol, it loses 3·52 per cent., or 2 eq. water; the same hydrate ($Amygd. + 4 HO$) is obtained crystallized, from a boiling saturated solution of amygdalin in alcohol of 80 per cent.

Amygdalic Acid. Syn. Amygdalinic acid. Discovered by Wöhler and Liebig. An aqueous solution of amygdalin, treated with caustic alkali, is wholly resolved into ammonia and amygdalic acid. Dissolve amygdalin in barytic water, boil the solution till ammonia ceases to be given off, precipitate the baryta exactly by sulphuric acid, filter and evaporate the liquid to dryness in a water-bath. In the formation of this acid, 1 eq. amygdalin and 2 eq. water are resolved into ammonia and amygdalic acid; $C_{40}H_{27}NO_{22} + 2HO = C_{40}H_{26}O_{24} + NH_3$.

The acid thus obtained is a colorless, transparent, gummy mass, of acid taste and reaction; exposed for some time to heat, exhibits traces of crystallization; it is deliquescent, insoluble in ether and absolute alcohol, but somewhat soluble in spt. of wine. The acid, or its salts, heated with nitric acid, or with binoxide of manganese and sulphuric acid, is resolved into volatile oil, formic and carbonic acids. It forms soluble salts with all bases, excepting the basic salt of lead. Form., $HO, C_{40}H_{26}O_{24}$.

Amygdalates. Amygdalate of *Baryta* is prepared as above, the excess of baryta precipitated by carbonic acid, the solution concentrated, filtered, and evaporated to dryness in a water-bath. It is a white, amorphous, gummy mass, losing water at 284° , and becoming milk-white; it may now be easily pulverized, and again takes up 7 per cent. water; it may be heated to 374° without decomposition. Form., $BaO, C_{40}H_{26}O_{24}$.

Amygd. of *Lead* obtained by double decomposition; much of it is dissolved during edulcoration, and the undissolved portion, after drying, contains much carbonate of lead.

Amygd. of *Silver* is soluble, but the solution soon begins to deposit metallic silver, and to smell of formic acid. The formulæ of these salts similar to that of baryta.

Decomposition of Amygdalin by Emulsin. The remarkable conversion of amygdalin into volatile oil of bitter almonds (hydruret of benzoyl), was first observed by Robiquet and Boutron-Charlard, but more fully developed by Wöhler and Liebig, subsequent to their masterly essay on Benzoyl. Both the sweet and bitter almonds consist, in a large proportion, of an albuminous principle, termed *emulsin*, by which, and with which, the amygdalin, in contact with water, suffers a peculiar change, and the resulting products are the volatile oil, prussic and formic acids, sugar, &c. When 10 pts. amygdalin are dissolved in 100 pts. water, and mixed with an emulsion of sweet almonds, or with 1 pt. *emulsin* in 10 water, this change instantly commences; the solutions remain clear, but exhibit a faint opalescence; the odor of bitter almonds is instantly perceived, and, by distillation, prussic acid and the volatile oil pass over with water; the residue in the retort, rendered turbid by the

coagulated emulsin, is evaporated, when it yields a syrup containing a crystallizable sugar; after destroying the sugar by fermentation, the residue still contains a fixed acid. The amount of sugar obtained is greater than the elements of amygdalin could produce, and hence it would seem that the elements of emulsin, by its decomposition, tend to the formation of sugar. There is no doubt that the elements of water also contribute to the transformations. The complete decomposition depends on the quantity of water employed, which must be sufficient to dissolve the generating hydruret of benzoyl; otherwise a portion of amygdalin remains undecomposed. The emulsin used must also be in its uncoagulated state, for if coagulated by heat, its catalytic power is destroyed; hence Robiquet and Boutron-Charlard could not obtain the vol. oil after the almond-cake had been boiled with alcohol.

The complex nature of amygdalin, and the large number of equivalents in its composition would lead to an inference of its capability of varied transformations. Although, as Berzelius remarks, some of the resulting bodies which W. and L. found, such as gum, may be educts or original constituents of the almonds merely extracted, yet, according to W. and L., we may ascribe them solely to the decomposition of amygdalin; thus,

1 eq. cyanohydric acid.....	NC_2H
2 eq. hydruret of benzoyl.....	$\text{C}_{25}\text{H}_{12}\text{O}_4$
$\frac{1}{2}$ eq. sugar.....	$\text{C}_6\text{H}_5\text{O}_5$
2 eq. formic acid.....	$\text{C}_4\text{H}_2\text{O}_6$
7 eq. water.....	H_7O_7
1 eq. amygdalin.....	$\text{NC}_{40}\text{H}_{27}\text{O}_{22}$

E. Simon examined several kinds of vegetable albumen, to determine their power of converting amygdalin into volatile oil of bitter almonds. The albumen was prepared by making an emulsion of 1 pt. of the bruised seed with 8 pts. water, coagulating this by alcohol, drying and powdering the coagulum, freeing from fixed oil by ether, and washing by alcohol. The albumen of bitter almonds was most energetic and effectual in producing the conversion of amygdalin; that of sweet almonds but little inferior to it; that from poppy seed produced the odor of the volatile oil after a couple of days; and still more feeble was the albumen from hemp seed, and the black and white mustard seed, although the action did take place. *Pogg. An.* xliii. 404.

Application to the Preparation of Volatile Oil of Bitter Almonds, &c. Amygdalin and emulsin being in distinct cells in the cotyledon of the bitter almond, together with the fixed oil, cannot act on each other, and are still farther prevented by removing water by drying them. The fixed oil is separated by pressure, and upon boiling the residual cake with alcohol, the emulsin is coagulated and amygdalin extracted. When the cake is moistened with cold or lukewarm water, the odor and taste of prussic acid and the volatile oil are at once

perceived; but if the quantity of water be too small, a portion of amygdalin is undecomposed, and may be extracted by alcohol. The decomposition commences instantly, but requires some time for a complete transformation, so that but little oil would be obtained by hastily distilling the mixture, as the emulsin would be coagulated and farther action cease. The same result takes place when the pressed cake is thrown into boiling water, the emulsin being instantly coagulated and rendered inert.

To obtain the volatile oil, or distilled water of bitter almonds, the almond cake, after the removal of the fixed oil, is made into a thin paste with lukewarm water, left for 24 hours in a closed bottle, and distilled in a water or chloride of calcium bath. 100 pts. of amygdalin yield 47 pts. of crude oil, which 47 pts. contain 5.9 pts. of free prussic acid.

Distilled water of Bitter Almonds, is prepared by mixing 2 lb. bitter almonds, freed from fixed oil by pressure, into a thin paste, with water in a close vessel, and after macerating 12 hours to distil off 2 lb., avoiding too high a heat.

Prop. A milky liquid, having the odor and taste of prussic acid and volatile oil; generally depositing some of the oil with prussic acid by standing. When fresh, one ounce contains $1\frac{1}{4}$ grains of anhydrous prussic acid; it is, however, liable to diminish in strength, by keeping. To remedy this inconvenience, W. and L. have proposed an excellent process for preparing the distilled water, of more certain strength than that ordinarily employed. In one ounce of emulsion of sweet almonds, containing 2 drs. almonds, dissolve 17 grs. amygdalin. Since 100 grs. amygdalin produce 5.9 grs. dry prussic acid, this mixture will contain 1 grain of anhydrous acid, and does not require distillation. Dry amygdalin will keep perfectly well, and hence, this mixture being made in the quantities required for immediate use, is preferable to that prepared by any other process.

When nitrate of silver is added to the almond-water, cyanide of silver is not precipitated, but when ammoniacal nitrate of silver is added, and the ammonia neutralized, after some time, by nitric acid, the cyanide is perfectly precipitated. The almond-water, evaporated with chlorohydric acid, yields a residue of formobenzoic acid and sal-ammoniac. See ALMOND, BENZYL, EMULSIN, and LAUREL-water.

AMYL.* *Chem.* Syn. Amule. The hypothetical radical of a series of organic bodies, one of which, the hydrated oxide of amyl, has been long known as the Oil of Potato-Spirit, being produced in the fermentation of grain and potatoes. From the composition, and modes of decomposition of its compounds, it is believed to be an alcohol. The following table presents these compounds, which we shall describe, and compares them with the corresponding compounds of ethyl.

* The prevailing use of the termination *yl* for organic radicals, induces us to employ it during the remainder of the present work, instead of the termination *ule*, heretofore adopted.

AMYL.

$C_{10}H_{11} = \text{Ayl}$	Amyl—unknown
$C_{10}H_{11}O = \text{AylO}$	Oxide of amyl
$C_{10}H_{11}O, HO$	Oil of potatoes
$C_{10}H_{11}Cl = \text{Ayl Cl}$	Chloride of amyl
$C_{10}H_{11}Br$	Bromide “
$C_{10}H_{11}I$	Iodide “
$C_{10}H_{11}O, HO, 2 SO_3$	Sulphamilic acid
$C_{10}H_{11}O, BaO, 2 SO_3$	Sulphamilate of baryta
$C_{10}H_{11}O, C_4H_3O_3$	Acetate of oxide of amyl
$C_{10}H_9O, C_4H_3O_3$	Chlorinated ditto.
$C_{10}H_{10}$	Amilen
$C_{10}H_9O, HO$	Amilic aldehyde
$C_{10}H_9O_3, HO$	Valeric acid

AMYL.

C_2H_5	Ethyl
C_4H_5O	Ether (oxide of ethyl)
C_4H_5O, HO	Alcohol
C_4H_5Cl	Chlorhydric ether
C_4H_5Br	Bromhydric “
C_4H_5I	Iodhydric “
$C_4H_5O, HO, 2 SO_3$	Sulphovinic acid
$C_4H_5O, BaO, 2 SO_3$	Sulphovinate of baryta
$C_4H_5O, C_4H_3O_3$	Acetic ether
$C_4Cl_2O, C_4H_3O_3$	Chlorinat. acetic ether
C_4H_4	Olefiant gas (etheren)
C_4H_3O, HO	Aldehyde
$C_4H_3O_3, HO$	Acetic acid. (Graham.)

1. *Hydrated Oxide of Amyl.* Syn. Oil of Potato-Spirit; Fousel-oil; Amilic Alcohol, Bihydrate of amilen. Ger. Fuselöl. Amyloxydhydrat. It was first observed by Scheele in the spirituous liquor obtained by distilling fermented potatoes, and has since been investigated by Pelletan, its general character pointed out by Dumas, and minutely and ably studied by Cahours.

Prep. Towards the close of the distillation of the alcoholic spirit from potatoes, a milky liquid passes over, which, by standing, deposits the fousel oil, mixed with about an equal quantity of alcohol and water. To purify it, it is shaken several times with water, dried by remaining in contact with chloride of calcium, and redistilled. Alcohol and water pass over first, and as soon as the temperature rises to 270° , the receiver is changed, and pure amilic alcohol distils over.

Prop. It is a colorless, limpid, very mobile, and yet oily liquid, with a strong odor, at first agreeable, but soon becomes highly offensive and nauseous; when inhaled, it causes asthmatic pains in the chest, with coughing, and even vomiting; taste very acrid. It gives a stain on paper which soon disappears. It burns with a bluish-white flame, but is extinguished, unless heated or with a wick; boils at 270° ; spec. grav. of liquid = 0.8124 at 60° , of its vapor = 3147 , representing 4 volumes; congeals at -2° or -4° in crystalline plates. Water dissolves it very sparingly, acquires its odor and the faculty of making beads by shaking; it is miscible in all proportions with alcohol, ether, strong acetic acid, and the fixed and volatile oils. It dissolves sulphur, phosphorus, and iodine without alteration; it may also be mixed, without change, with solutions of potassa or soda, but when heated with dry potassa, hydrogen is evolved, and valerate of potassa formed. It absorbs chlorhydric acid gas largely, attended with the evolution of heat; with sulphuric it forms sulphamilic acid, &c.; distilled with dry phosphoric acid, it yields a hydrocarbon, called amilen. According to Gerhardt, it unites directly with bichloride of tin to a crystalline compound, which is slowly resolved again in the air, more rapidly in water, into its constituents. Form., $C_{10}H_{12}O_2 = C_{10}H_{11}O + HO$, or $\text{Ayl O} + HO$.

Chloride of Amyl. Ger. Amylchlorür. Prepared by distilling equal parts of fousel oil and perchloride of phosphorus. A colorless, oily liquid, of rather agreeable odor, boils at 216° ,

neutral to test-paper, insoluble in water, and produces no action on nitrate of silver. Form., $C_{10}H_{11}Cl$, or Ayl Cl .

Chlorinated Chloride of Amyl. The final result of the action of chlorine on fousel oil, in a bottle exposed to sun-light; a colorless liquid of strong odor, reminding of camphor. Form., $C_{10}H_3Cl_8$; 8 equivs. of hydrogen being replaced by as many of chlorine.

Iodide of Amyl. Fr. Hydriodate d'amilene, Cahours. Distil 8 pts. iodine, 15 pts. fousel oil, and 1 pt. phosphorus, wash the product with water, dry it with chloride of calcium and redistil. A colorless liquid, heavier than water, of an alliaceous odor and pungent taste; decomposed by light, iodine being evolved; an alcoholic solution of caustic potassa, but not the aqueous, decomposes it readily. The calculated grav. of the vapor = 6835 , by experiment 6675 . Form., $C_{10}H_{11}I$, or Ayl I .

Bromide of Amyl. Fr. Hydrobromate d'amilene, Cahours. Obtained like the preceding, with bromine, and resembles it closely in its properties. Form., $C_{10}H_{11}Br$, or Ayl Br .

Bisulphate of Oxide of Amyl. Syn. Sulphoamilic acid. When the sulpho-amilate of baryta is exactly decomposed by sulphuric acid, the clear solution, containing the salt or acid in question, is evaporated in air, or in vacuo, to a syrupy consistence, when fine needle-shaped crystals are sometimes deposited. If the solution be boiled, sulphuric acid is set free, and the amilic alcohol separates as an oily stratum. It is not known in a very pure state, but it bears a strong analogy to sulphovinic acid, and forms double salts or sulphamilates, which are all soluble in water. Form., $C_{10}H_{11}O, HO, 2 SO_3$, or $\text{Ayl O}, HO, 2 SO_3$.

Sulphamilate of Potassa. Syn. Sulphate of Potassa and Amyl. Formed by adding carbonate of potassa to the following barytic salt; white needles or plates, of a very bitter taste, and very soluble in water and in alcohol. Form., $C_{10}H_{11}O, KO, 2 SO_3$, or $\text{Ayl O}, KO, 2 SO_3$.

Sulphamilate of Baryta. *Prep.* When equal parts of oil of vitriol and fousel oil are mixed, combination takes place, with the appearance of a violet color; neutralize with carbonate of baryta, which precipitates a portion of sulphate of baryta, leaving the double sulphate of baryta and amyl in solution; purify by animal charcoal, and evaporate. Pearly crystalline laminae, very solu-

ble in water and in alcohol, very slightly in ether, of a bitter taste; the solution decomposed by boiling. The crystals contain 3 eq. water, one of which is lost at 212° , and the dry salt decomposed at 392° . Form., $C_{10}H_{11}O$, BaO , $2SO_3 + 3HO$, or $AyIO$, BaO , $2SO_3 + 3aq$.

Sulphamate of Lime or Lead. Similar salts are formed with lime and with oxide of lead, which take up 2 eq. water in crystallizing, and their solutions are decomposed, by boiling, similarly to the preceding; the lime-salt appears to be more soluble in cold than in hot water. Form., $C_{10}H_{11}O$, CaO , $2SO_3 + 2HO$, and $C_{10}H_{11}O$, PbO , $2SO_3 + 2HO$.

Acetate of Oxide of Amyl. Fr. Acetate d'amilene. Prep. Distil a mixture of 2 pts. acetate of potassa, 1 pt. fousel oil and 1 pt. oil of vitriol; dry it by chloride of calcium, and rectify with a little oxide of lead. A colorless liquid, of an ethereal and aromatic odor, boiling at 257° , lighter than water, in which it is insoluble, but is soluble in alcohol and ether. It is slowly altered by contact with an aqueous solution of potassa, by an alcoholic solution rapidly, the oil being liberated, and acetate of potassa formed. Spec. grav. of vapor 4475; combining measure 4 vols. Form., $C_{10}H_{11}O$, $C_4H_3O_3$, or $AyIO$, AcO_3 .

Chlorinated Acetate of Oxide of Amyl. Prepared by saturating the preceding acetate with chlorine, at a temperature increasing to 212° . A colorless liquid, of neutral reaction, insoluble in water, becomes of a yellow color, and is decomposed by a heat above 302° . $C_{10}H_9O$, $C_4H_3O_3$. See chlorinated acetic ether in the above table, and under ACETULE. When exposed to the farther action of chlorine, in sunshine, a crystalline body results, containing more chlorine, which has not been farther examined.

When fousel oil is oxidized by contact with air, or when distilled with caustic potassa, an acid is obtained similar in all respects to that procured from the valerian-root; the resulting change is the replacement of 2 eq. hydrogen by 2 eq. oxygen, in which it agrees with common and wood alcohols, which, in like manner, produce acetic and formic acids. The following table of the three alcohols and their derivative acids, will place this in a clearer light:

C_4H_5O , HO = Common alcohol.
 $C_4H_3O_3$, HO = Acetic acid.
 C_2H_3O , HO = Wood-alcohol.
 $C_2H_3O_3$, HO = Formic acid.
 $C_{10}H_{11}O$, HO = Amilic alcohol
 $C_{10}H_9O_3$, HO = Valeric acid

See VALERIC Acid.

Amilen or Amylen. When fousel oil is repeatedly distilled with anhydrous phosphoric acid, a colorless liquid is obtained, lighter than water, of a peculiar aromatic odor; boils at 320° ; its vapor has a spec. grav. = 5061 by experiment, or $4902 (= \frac{9803.8}{2})$ by calculation; combining measure = 2 vols. By analysis, it has the same percentage composition as olefant

gas, etherin, and cetin, and is regarded on the etherin-view as the basis of the amilic series. See the Etherin-theory under ETHER. Form., $C_{10}H_{10}$.

Gaultier de Claubry examined a compound, obtained in the distillation of fermented beet-root molasses, which, when purified, proved to be the oil of potato-spirit. The crude product obtained by the distillation is a liquid, heavier than alcohol, of a penetrating odor, painful to inhale, of a sharp, very disagreeable taste. Although the crude product obtained by the action of sulphuric acid on the fousel-oil is very complex, G. de C. succeeded in separating the 4 following distinct substances from it:

1. A colorless liquid, of a strong, penetrating odor, difficult of inhalation, a strong and bitter taste, boiling at 205° , soluble in sulphuric acid. He found it composed according to the formula, $C_{10}H_{11}O_2$.

2. A colorless and tasteless liquid, of an agreeable ethereal odor, boiling at 338° , soluble in sulphuric acid, which colors it of a beautiful red. Form., $C_{10}H_{11}O$; which is that of oxide of amyl or amilic ether.

3. A liquid of a disagreeable odor, resembling rotten apples, boiling at 320° , insoluble in and not colored by sulphuric acid. Formula, $C_{10}H_{10}$, which would represent amilen.

4. A liquid of ethereal odor, and a strong, but not bitter taste, the formula of which appeared to be $C_{10}H_{11}O_2$, but G. de C. believes it to be a mixture of the preceding with another body.

The beet-root fousel oil itself gave, in the analysis, numbers which led to the well-known formula of potato fousel oil, $C_{10}H_{12}O_2$.

Unless there be a typographic error in the *An. der Chem. and Ph.* xlv. 128, from which this notice is drawn, the remark that the 1st liquid is the amilic aldehyde is incorrect, for then its formula would be $C_{10}H_{10}O_2$. See ALCOHOL, ETHYL, and FOUSEL OIL.

AMYLATE. Chem. The compound of starch, with a base: thus, amylate of lead = $C_{10}H_{10}O_2 + 2PbO$.

AMYLUM. Chem. See STARCH.

ANACARDIUM. Bot. Syn. Cashew. The stem of this tree yields a milky juice, that stains cotton or linen of a deep black, by exposure to the air. The fruit has a sub-acid taste, slightly astringent, and its expressed juice yields a pleasant wine, or by distillation, a liquor said to be superior to arrack. Between the two shells of the nut is a viscid oil, of a pungent, burning taste, very caustic, and hence applied externally to ring-worms, &c.; it changes to a brownish color by exposure, and is hence applied to writing names on cotton and linen, which are indelible. The tree farther yields some 10—12 lb. of a gum, resembling arabic gum, but possesses, at the same time, a slight astringency.

ANALCIME. Min. Syn. Kubizit, Wern.; Hexaedrisches Kuphonspath, Mohs.; Cuboit, Breith. Descrip. Cryst. regular system. 24-hedron of 1:2, 24-hedron and cube, cube with 12-hedron, and sometimes 8-hedron; cleavage apparently parallel to cube. H = 5.5. G = 2.07—2.3. Colorless, and transparent, or gray-

ANALCIME.

ish, greenish, yellowish, reddish white, flesh red, and opaque; lustre shining, vitreous, rarely pearly; fracture imperfectly conchoidal and uneven; brittle; becomes feebly electric by friction, hence its name, signifying, *without force*.

Behavior. In matrass, gives water, and becomes milk-white; on charcoal, swells, and with a strong heat, fuses to a diaphanous bead without intumescence; dissolved by borax and mic. salt, leaving a skeleton of silica in the

ANALCIME.

latter. When finely powdered, perfectly decomposed by muriatic acid, the silica imperfectly gelatinizing; after ignition more difficultly soluble.

Analysis. 1, by Vauquelin; 2, 3, by H. Rose, from Fassathal; 4, by Connel, from Old-Kilpatrick, in Dumbartonshire; 5, by Henry, from Blagodan, in the Ural; 6, by Thomson, from the Giant's Causeway; and, 7, the calculated per cent. by the formula given below.

	1.	2.	3.	4.	5.	6.
Silica.....	58	55.12	56.47	55.07	57.34	55.60
Alumina.....	18	22.99	21.98	22.23	22.58	23.00
Soda.....	10	13.53	13.78	13.71	11.86	14.65
Potassa.....	—	—	—	—	0.55	—
Lime.....	2	—	—	—	0.35	—
Water.....	8.5	8.27	8.81	8.22	9.00	7.90
	96.5	99.91	100.99	99.23	101.68	101.15

The 3d analysis by Rose, was of the variety called *Sarcolite*.

Form., $3 \text{NaO}, 2 \text{SiO}_3 + 3 (\text{Al}_2\text{O}_3, 2 \text{SiO}_3) + 6 \text{HO}$, or a hydrous $\frac{2}{3}$ silicate.

Localities. Transparent crystals, near Catania, which, with the Tyrolese, are cubes, with the 24-hedron on its solid angles; in Dumbartonshire they are often large, and only 24-

hedra. It occurs farther on the Faroe Isles, Iceland, &c., in basalt, trap; at Arendal, Norway, in iron-ore; at Andreasberg, Harz, in silver-mines; in the ancient lavas of Vesuvius. Its general occurrence is in basaltic and trap-pean rocks, associated with other zeolitic minerals.

ANALYSIS.

THAT branch of applied chemistry, which has for its object the separation of bodies into their component parts, so as to recognise and prove the existence of them, and to estimate their quantity, is called *analytical chemistry*, and the series of processes which is necessary for its performance, is termed *chemical analysis*.

Chemical analysis embraces, therefore, two distinct parts: 1, to find the different ingredients of which a substance is composed; and, 2, to determine the quantity in which they exist in it. The former is designated by the name of *qualitative analysis*, and must always precede the latter, which is termed *quantitative analysis*. As matter cannot be destroyed, the weight of all the component parts must equal the weight of the whole body. If the latter, therefore, be the result of the quantitative analysis, it confirms greatly the correctness of the qualitative analysis, that no ingredient has escaped our notice; but not absolutely so, since two or more ingredients resembling each other, and following together in the quantitative estimation, may have been mistaken for one; while, on the other hand, if the joint weight of all the component parts do not equal that of the whole body, and this deficiency cannot be accounted for by any imperfection in the methods employed, it proves conclusively, that some ingredient has escaped our notice.

To analyze a substance, does not necessarily imply the separation of the substance into its component parts, so as to have them all in a perfectly free state; for some of them would be found endowed with such powerful affinities, that it would be a matter of extreme difficulty to obtain them in their free state, and still more difficult, if not impossible, to retain them so; in most cases, therefore, we merely transfer the component parts of the substance under analysis to combinations, the nature and composition of which is well known.

The reverse process of analysis is synthesis, by which we again produce a substance from its component parts; but as certain substances often combine only under peculiar circumstances, it will be evident that, unless we know these circumstances, or are able to contrive them, the synthesis of the substance under such circumstances will remain impracticable, but does not, therefore, in the slightest degree, impair the correctness of our analysis.

Chemical analysis requires, more than any other branch of applied chemistry, a thorough knowledge of the science of chemistry; but it is, on the other hand, itself the base of all chemical knowledge, since it alone enables us to investigate the changes which take place whenever chemical affinity is called into action, and to ascertain the laws which govern them, by ascertaining the exact composition of the resulting compounds. The progress of the

science of chemistry, and the perfection of analytical chemistry, have, therefore, always kept pace with each other.

It is not within the limits of this work to enter deeply into the extensive details of analytical chemistry, but our object will be, first, to give a general view of the principles of this science adapted to the general inquirer, or to those who, perhaps, by their occupations, may have become acquainted with some particular branch, and are desirous of a more general knowledge of it. Secondly, to illustrate the application of these principles by applying them to some particular instances, selected with a view to their general occurrence, and the consequent interest attached to them; or to their importance in a technical or economical point of view, and to refer those who are desirous of studying it in all its details, either for scientific or professional pursuits, to the laboratory of some analytical chemist. For, it would be more than useless, without the assistance of a practical chemist, to hope to master a science, the success of which depends as much on practical skill and ingenuity as on a true knowledge of the principles of the science itself. At the same time, we refer the more advanced students to the different treatises and manuals on analytical chemistry, more particularly to those of Berzelius and Rose, and to the attentive perusal of detailed accounts of analyses performed by chemists of established reputation, and published in the different scientific periodicals.

GENERAL PRINCIPLES OF CHEMICAL ANALYSIS.

A substance is either a simple body, an element, or a chemical combination, or a mechanical mixture of them. An example will illustrate this. Hydrogen and chlorine gases are both elementary bodies, viz.: such as chemistry is not capable of further separating into others, but which may be recovered again from all combinations in which they exist. If these be mixed in equal volumes, we have a mechanical mixture of two elementary bodies, which again may be separated without the aid of chemical means, as by mere absorbents. But if the mixture be exposed to the sun's rays, they suddenly enter into chemical combination, which is made apparent by a flash of fire passing through the whole mass. The gas suffers hereby no change in volume nor in weight, but, on examination, it will be found to have entirely different properties from either hydrogen or chlorine, or their mixture; it is an entirely different gas, called chlorohydric acid gas, from which neither of its constituent elements can be separated by any merely mechanical means. If any of the two gases were added in a larger proportion than equal volumes, we should still have the same occur

rence, but instead of the whole of the gas being converted into chlorohydric acid gas, we should have this latter gas, mechanically mixed with the gas added in excess, or a mechanical mixture of a chemical compound with an element.

A *mechanical mixture* may often be separated by mere mechanical means into its component parts, which may then be recognised as substances of known chemical composition. Thus, a mixture of a light and a heavy powder may often be separated by washing with water, which will float off the lighter. Although, in such cases, where we employ purely mechanical means to separate mixtures into their component parts, the operation ought strictly not to be called analysis, at least not chemical analysis; still ordinary language does not draw this distinction, principally where the quantitative estimation of any of the component parts is the main object. We might thus say, the *analysis* of a magnetic iron ore, when it is pulverized, and the ore separated from the gangue by extraction with a magnet, in order to determine their relative quantity.

The modern improvements in the microscope and its use afford to chemistry an invaluable means of discovering component parts, where they exist merely as mechanical admixtures, when chemistry alone would be unable to decide it. Thus, the long-contested question among chemists, whether Kermes mineral contained oxide of antimony, as an essential or chemically combined part, was decided by the aid of the microscope, by showing the oxide of antimony to exist in it in the state of exceedingly minute crystals, and therefore not in chemical combination with the sulphuret of antimony. Mechanical mixtures may further be separated by mere absorbents or perfectly neutral solvents, which take up some of its parts and leave others behind; and if, on the other hand, a substance be taken up from a mixture by a solvent, to which it otherwise is perfectly indifferent, or has no chemical affinity, there is good reason to believe that it existed merely as mechanical admixture. Or some or all the ingredients may be taken up by a solvent and afterwards separated by crystallization, or by precipitation, by the addition of other perfectly neutral solvents to the first.

Mechanical mixtures may also be analysed by more purely chemical means, such as dissolving reagents, if some of the admixtures be acted on by them, while others are not affected. If we thus treat a mixture of carbonate of lime and silica with a dilute acid, the latter dissolves the lime, with expulsion of the carbonic acid, while insoluble silica is left behind. A very considerable number of what are commonly called chemical analyses are nothing more than the separation of mechanical mixtures by the two last-mentioned means. Thus, a great many analyses of parts of plants or animals, by which they are separated by different solvents into different neutral substances, such as sugar, starch, gum, lignin, volatile oil, &c., are nothing more than a separation of a mechanical mixture of these substances. Heat and other such agents may also be often used for the same purpose: thus, mixtures of dif-

ferent fatty matters of different fusibility, may be separated by cautious fusion; or liquors of different volatility by distillation.

It is mostly in analysis for scientific purposes that it is of importance to ascertain whether a substance is a pure chemical combination or a mechanical mixture of several compounds. For most practical purposes the main object is merely to find the ingredients, it being of little or no interest whether these are in chemical combination or merely mixed together. If, therefore, inspection does not lead to distinguish the ingredients, their separation is effected as if it were a chemical combination, without reference to its mixed nature.

It has already been stated that all substances are either elementary bodies or their chemical combinations, or mechanical mixtures of both. Those substances which chemistry is not capable of separating into others, it calls elementary bodies, and then proves all the rest to be formed by their union or combination. Two elements form, by their union, binary combinations, but when these again combine, the result is a more compound body, containing three or more elements. On the other hand, most of the more compound bodies may again be separated into binary, or at least less compound bodies. These latter are then said to be the *proximate constituents* of the more compound body, while the elementary bodies into which it is finally resolved, are called its *ultimate constituents* or *elements*. Thus, oxygen combines with sulphur, forming sulphuric acid, and with potassium, forming oxide of potassium or potassa; but sulphuric acid combines again with potassa, and forms sulphate of potassa. Oxygen, sulphur, and potassium, are then said to be the ultimate constituents or elements of sulphate of potassa, while sulphuric acid and potassa are its proximate constituents. When the proximate constituents of a substance are known, we may generally infer from them the ultimate constituents; and, vice versa, if the ultimate elements are known, theoretical chemistry will generally teach us which are the proximate constituents. Analysis may, therefore, in more compound bodies, discover and determine either the proximate constituents, or the elements. This is altogether accidental, and depends on the peculiar method adopted, or on the facility with which either the proximate constituents or the elements are detected and estimated. Thus, for instance, if the above substance, sulphate of potassa, were unknown to us, and therefore subjected to analysis, whether we should first discover the sulphur or the sulphuric acid, would probably depend on the method adopted. If we first examine it by the blowpipe, the sulphur would probably be first made apparent; while, if we first tested it in the moist way, we should recognise the sulphuric acid. In the same manner, in determining the relative quantity of the constituents, we should neither estimate directly the quantity of sulphur by itself, nor that of the sulphuric acid, but transfer them both to a combination, from the quantity of which, either that of the sulphur or of the sulphuric acid may be calculated with equal facility. It is therefore indifferent of itself,

whether we give the result of the analysis in so many parts of sulphur, oxygen, and potassium, or so many parts of sulphuric acid and potassa. Convenience and custom, or theoretical notions, decide here, as in other matters.

In regard to the analysis of *chemical combinations*, it may be remarked that, as it is a necessary consequence of chemical combination, that the constituents, either ultimate or proximate, which enter into combination, necessarily alter more or less their original nature and properties; none of the constituents of an unknown chemical combination can be recognised with certainty in it from its nature and properties. It will therefore be seen, that in order to find what constituents it is composed of, it becomes necessary to overcome the affinities by which the latter are held in combination, so as either to set them free and make them appear with their original properties, by which they may be recognised, or to transfer them to other combinations, which are either known or may be recognised. It would thus be impossible to recognise hydrogen or chlorine in chlorohydric acid gas; nothing could be more totally different from either of its constituents. But, if we introduce a piece of metallic zinc into the gas, the affinity of the zinc to the chlorine will overcome the affinity of chlorine to hydrogen. The chlorine will therefore be taken up by the zinc, and leave the hydrogen in its free state, which can then be recognised by its usual properties. Another mean which analytical chemistry employs for overcoming existing affinities and setting the ingredients free, or transferring them to other combinations, is *heat*, which often will induce the gaseous elements to separate and assume their free state. Oxide of mercury may thus be separated into its two elements, oxygen gas and metallic mercury. Carbonate of lime is separated by ignition into carbonic acid gas and lime. Volatile liquids and solids may also be expelled by heat from their combinations, by their tendency to assume the gaseous state at higher temperatures. Thus, chemically combined water is generally discovered by heating the substance in the closed end of a glass tube, when it will be expelled, and condense in the colder part of the tube. *Electricity* is another agency for overcoming affinity. It was by this agency that Humphry Davy discovered the metallic radicals, and the compound nature of the alkalis. But the mean most often made use of in analyses of substances is *chemical affinity* itself, either single or double elective affinity. In the former case we have a combination of two constituents, and present to it a third substance, for which one of the constituents has a greater affinity than for the other, and therefore leaves the latter in its free state, and combines with the substance added. Thus, if uric acid be in a solution, combined with a base, and a stronger acid be added, to which the base has a greater affinity, it will combine with the latter, and leave the uric acid, which thereby is separated in its free state, as an insoluble powder; or if sulphuric acid be added to a solution containing baryta, the affinity of the latter for sulphuric acid is greater than for any other acid. It will there-

fore combine with it, and separate as an insoluble and easily recognisable compound, sulphate of baryta. What single affinity is unable to effect, may be accomplished by double affinity. Thus, if oxalate of lime were given us for analysis, we should not be able to separate the oxalic acid from the lime by any acid or base alone; but if we treat it with carbonate of potassa, the affinity of the potassa for the oxalic acid, and that of the carbonic acid for the lime, act at the same time, and we decompose it into oxalate of potassa and carbonate of lime, in which compounds the oxalic acid and the lime are easily detected.

When thus liberated, or transferred to other combinations, we employ various means to recognise the ingredients, or the new compounds to which they are transferred, as their *physical properties*, such as peculiar or striking colors; thus, the presence of manganese in a substance, is recognised by the green color which it yields, when fused with nitre and carbonate of soda, owing to a combination, which it always forms under these circumstances; or by their peculiar odor or taste; thus, acetic acid, when liberated, is, in most cases, recognised by its peculiar odor, and the different kinds of sugar by their taste. The senses of smelling and tasting are of no less importance to the analytical chemist than the sight, and are capable of considerable cultivation. It is particularly in organic analysis that they are invaluable, as affording the only means of discovering many of the organic proximate constituents. Of no less importance are the different forms of aggregation, which the ingredients or their new combinations assume, as, for instance, whether they appear as a gas or a liquid, or an insoluble solid. This latter is of particular importance, and we therefore generally try to effect a solution of the substance, and then add different other substances, mostly in solution, with which the different ingredients form compounds, which separate, and are distinguished by their different degrees of insolubility, or peculiar form of aggregation, such as whether they be heavy or light, pulverulent, flocculent, crystalline, &c.

The substances we add for the sake of separating or combining with the ingredients of the substance under examination, are called *reagents*; if they produce any change with them, they are said to react with them; if they form insoluble compounds, which separate, they *precipitate* them; if the produced change or compound be such as to lead to the recognition of the ingredient, it is said to be a *test* for it. Thus, when a solution of iodine is added to a solution containing starch, it produces a beautiful blue color. As iodine produces this color with no other substance than starch, we say that iodine is a test for starch. Or if we add a solution of a salt of baryta to a solution containing sulphuric acid, the latter precipitates in combination with baryta, as sulphate of baryta, which remains insoluble by the addition of chlorohydric acid. As no other substance forms a similar precipitate with barytic salts, insoluble in water and an excess of chlorohydric acid, baryta is said to be a test for sulphuric acid. The insolubility of

the compounds formed by the addition of reagents with the different ingredients, becomes of still more importance, since it affords the means of removing them, either for the sake of further examining them, or of preventing them from interfering, by their presence, with the discovery and recognition of the other ingredients.

In this way, all the different ingredients of a substance, may be recognised by adding the different reagents and tests to different portions of the substance, or by applying them successively to the same portion, removing, if necessary, the ingredients, as they are recognised. But, by such indiscriminate or random application of reagents, it would not be possible to prevent some ingredients from escaping notice. It therefore becomes necessary to introduce a systematic method of proceeding in the application of the reagents. As the reagents, for their action, always require more or less fluidity, this may either be attained by heat or fusion, or by solution. Hence, the distinction between *analysis in the dry* and *in the moist or humid way*. The qualitative examination by the former method is generally performed more or less in connection with the blowpipe, by which we fuse small beads of different substances, and then observe the reactions which take place by adding small portions of the substance under examination, and its behavior by different treatments, and with different reagents. For some metallurgic purposes, fusion on larger scale in crucibles, by the aid of furnaces, is resorted to; but although testing, in the dry way, and by the blowpipe in particular, has been carried to a high degree of perfection, and is performed with a great deal of facility and convenience, it cannot compare, in point of completeness or systematic procedure, with that in the moist way. We shall, therefore, in the more detailed description of the application of the above principles of qualitative analysis, describe the method of testing in the moist way, and recur to the testing by the blowpipe, only where the latter is more convenient, as, for instance, for a preparatory examination, or even preferable on account of its greater speed and certainty; and in such cases we refer for the full description to the article **BLOWPIPE**.

By testing in the moist way, it always becomes an object to effect a solution of the substance, and then apply such reagents as will form insoluble compounds with a certain class or group of ingredients; then separate these, and apply another reagent, which will separate another class or group of ingredients, left in solution by the previous reagent, and so on. Thus, all known ingredients are separated into groups, containing only a certain number of them, which are themselves distinguished or separated from each other by other reagents and tests. The last class or group is formed by those ingredients which are not precipitated by any of the previously applied reagents, and it being known which such may be, their presence or absence may be ascertained by special tests for this purpose. The reagents which we thus most commonly make use of, are sulphuretted hydrogen and sulphohydrate of ammonium, to separate the

metals proper; ammonia for the earths; the alkaline carbonates for the earthy alkalines, and the last class is generally formed by the alkalies. The electro-negative elements and acids are mostly detected by tests applied for their special detection.

In this way, with some practice, a tolerable certainty may be obtained, that no ingredient has escaped our notice, which is still more confirmed by the subsequent quantitative analysis, when the joint weight of them all are found to equal that of the whole substance. But before proceeding to the quantitative estimation, it is generally necessary to confirm and verify the conclusions which we have drawn from the regular systematic course of our examination, as to the presence or absence of the different ingredients, either by the application of other characteristic tests for those we have discovered, or by varying our method of examination, by which we might have been led into doubts or errors about others. Such confirmatory experiments or tests ought never to be omitted; and in the manuals of analytical chemistry, a large proportion of their contents is generally devoted to the behavior of the different substances with most of the usually employed reagents, the greater portion of which will be found in the present work, under the heads of the different substances.

The elementary bodies themselves, when they occur as objects for analysis in their uncombined state, are recognised by their physical properties and their behavior to the different reagents, by which they are made to dissolve and enter into combinations, and may then be recognised as other ingredients.

After having determined what the ingredients are, of which a substance consists, it next remains to estimate their quantity. For this purpose one or more portions of the substance are employed, and the weight of the different ingredients obtained from them ascertained, and generally expressed in 100 parts or per cent. of the substance. The object of quantitative analysis is, therefore, to liberate the ingredients in such a state, or to transfer them to such combinations, that a complete separation of them or their new combinations may be effected, and the estimation of their quantity become possible.

The quantitative analysis, or, at least, the quantitative estimation of certain ingredients, is sometimes performed in the dry way, and is then termed the dry assay, or, simply, assaying. Thus, for many metallurgic operations, the ores are fused in a crucible, with certain reducing reagents and fluxes, by the draft of a furnace or in the blast of a forge, and the quantity of reduced metal obtained from the ore ascertained. But, although these operations are not without practical value, still they are at present performed equally well, and with much more accuracy, in the moist way. The estimation of the quantity of gold and silver in alloys, by cupellation, is another much-practised application of the dry assay; but even here it may be substituted, and with still greater accuracy, by the moist way; and this latter is always resorted to whenever it becomes desirable to estimate the quantity

of all the different ingredients which a substance contains.

It has been stated before, that chemical combinations have always the same composition. It is, therefore, not necessary that the ingredients should be weighed by themselves. Chemistry teaches us that when substances combine chemically, it is in certain fixed proportions (see Laws of Combination under AFFINITY), and that, therefore, pure chemical compounds always contain the same amount of their different constituents. When we, therefore, have separated an ingredient by transferring it to another chemical combination, it is only necessary to ascertain the quantity of this compound, and then, from its known composition, calculate the quantity of the ingredient, whose weight of the original substance we desired to know. Thus, if a substance contain sulphuric acid, it would be impossible to separate the acid completely by itself, or weigh it, in this state; but if any other solution, containing baryta, be added, all the sulphuric acid will combine with so much of the baryta as is necessary to form an insoluble compound, the sulphate of baryta, which is easily separated and weighed, and from the weight of which the weight of the sulphuric acid is calculated. It is also evident, that instead of ascertaining directly the weight of an ingredient or its new compound, the loss in weight which they cause in the remainder, by their separation or escape, may be ascertained. This is the case, where the separation is easily effected; but the state in which it separates either renders it unfit for weighing, or its collection or preparation for this purpose is rendered more difficult than the weighing of the remaining substances. Thus, oxide of lead combines chemically with water: by heating this compound the water is expelled as vapor. It is hence easier to weigh the oxide of lead subsequently to the expulsion of the water, than to condense the vapors completely, for the purpose of weighing them directly; but if the oxide of lead be, at the same time, combined with other volatile ingredients, as, for instance, in common white lead, which is a combination of oxide of lead with carbonic acid and water, it then becomes necessary to condense and collect the volatilized water, and ascertain its weight directly. Having then ascertained the loss of all the volatile matter and the weight of the condensed water, by subtracting the latter from the former, we obtain the loss or weight of the carbonic acid.

It often happens that two or more ingredients are easily separated together from the rest, but their separation from each other cannot be effected at all, or but with difficulty. In such cases, their joint weight, or that of the combination in which they are separated, is ascertained, and then different methods resorted to for determining their relative quantity, as, for instance, from their different *physical properties*. This is often resorted to in practical life, where, in mixtures of only certain substances, the value depends on their relative quantity. The specific gravity of such mixtures affords, in many cases, a mean of determining their relative quantity, which is often made use of, particu-

larly where one of the substances is water. Alcoholometry, or the method of determining the quantity of alcohol, in mixtures of alcohol and water, depends entirely on the difference of their specific gravity. All the various uses of hydrometers, for ascertaining the strength of substances, depend on the same principle. As soon, therefore, as other substances are added, besides those for which it was constructed, it ceases to be applicable to this purpose. The richness of many ores may be determined approximately by their specific gravity. Besides specific gravity, other physical properties may be employed, as different fusibilities; thus, the relative quantity of two different fatty matters has been determined from the point of fusion of their mixture. Other methods are derived from their relation to light or heat; thus, in mixtures of chloride of sodium and potassium, their relative quantity has been ascertained by the degree of cold which they produce by dissolving them in water.

In cases where two such substances have strong chemical, but similar affinities, and, therefore, are difficult to separate, but their combining weights are different, another method is frequently made use of in analytical chemistry, for which the rather improper name of *indirect analysis* has been proposed by Poggen-dorff. This method consists in separating them both together, by combining them with a third substance, and ascertaining the weight of this combination accurately; we then determine, in any other analytical way, the quantity of this third substance, which, subtracted from the former weight of their combination with it, gives the quantity of the mixture of them both; calculating, then, from their respective combining weights, the quantity which this third substance would have yielded with either of them alone, we are able to calculate, from the quantity actually obtained, the relative quantity in which they exist.

In some cases, where we are unable to separate an ingredient in any state or combination suitable for the estimation of its quantity, this can only be obtained by estimating the weight, successively, of all the other ingredients, and subtracting the joint weight of these from the weight of the whole substance; but it is evident that, in this case, any inaccuracy in the estimation of the other ingredients will fall upon it.

The preparation of a substance for analysis, and the subsequent separation of the ingredients, either for their recognition, or, more particularly, for their quantitative estimation, requires many mechanical operations and manipulations, such as pulverization, solution, precipitation, pouring, washing, filtration, ignition, weighing, &c., the perfect performance of which is of the greatest importance to the success of the analysis, but is often very tedious, and can only be learned by practice in a laboratory; yet a thorough knowledge of the principles on which they depend, will highly facilitate their acquisition. They are the rudiments of analytical chemistry, on which its performance depends; but as they often seem of a trifling nature, it requires some exertion of mind to submit to the drudgery

of acquiring them. As analytical chemistry is the base of all chemical investigation, the want of them forms a great obstacle to the pursuit of chemistry, and they should therefore be early attended to. The spilling of a drop in pouring, or the spirting during evaporation, will often spoil long-anticipated results, and a single moment's inattention be the cause of losing weeks of labor, at a point when the result was nearly within grasp. The inability or unwillingness to go through the laborious and tedious process of an analysis, or to repeat it when unsuccessful, is also a continual temptation to scientific mendacity, by anticipating and pronouncing analytical results which have never been obtained. But truth cannot be obtained without labor, and is inseparably connected with honesty; and although a false ambition may thereby obtain, temporarily, a desired object, merited discredit usually returns, in the end, upon its originator. As a rule, no results should ever be admitted in science, unless accompanied by the details of the experiments from which they are derived.

Notwithstanding the perfection of the methods and the utmost care, some small loss of the ingredients in the different operations of quantitative analysis cannot be avoided. In well-performed analyses, of ordinary difficulty, this ought not to exceed one per cent., and in most cases be less. Beginners are apt to obtain more than the true weight, which arises from imperfect washing of the precipitates, or from hygroscopic moisture, attracted during the weighing, &c. In analysis, for practical purposes, the loss or excess is often distributed proportionally on all the ingredients, so as to make up exactly 100 parts; but in all scientific investigations, it is an established principle to give the results exactly as they are obtained.

As all chemical compounds are formed by the combination of their ingredients, in certain and fixed proportions, which are multiples of their atomic weights, it becomes a strong proof of the correctness of our analysis of a pure chemical compound, if the percentic composition correspond with multiples of the atomic weights; and again, if the percentic weights of the different ingredients be simple multiples of their atomic weights, it affords a strong probability, that the substance analyzed is no mechanical mixture, but a true chemical compound. It therefore becomes desirable to find the number of atoms which corresponds to the percentage result of our analysis, and therefrom, if possible, to establish a chemical formula. This is done by dividing the percentage numbers by the atomic weights of the respective ingredients. The numbers thus obtained, express the relative number of atoms of the different ingredients; and in order to reduce them to small, and, if possible, whole numbers, the smallest may be made unity, and divided respectively into all the rest. How the number of atoms thus found is to be distributed, for the purpose of bringing it into a formula, in conformity with other similar combinations, depends entirely on theoretical views.

In regard to the history of analytical che-

mistry, its progress has, as might be supposed, been inseparably connected with that of the science of chemistry itself. Bergman, Scheele, Klaproth, and others, improved the analytical methods considerably, but it was only after the development, by Richter, of the doctrine of the fixed proportions in which substances combine, that it was elevated to the rank of a science. It is, in a great measure, to the unremitting labors of Berzelius, and his accurate determination of the fundamental or combining numbers, that it is indebted to its present perfection. The ultimate analysis of organic bodies is also indebted, for its present perfection, to the improvements of Liebig and several others.

APPLICATION OF THE PRINCIPLES OF ANALYTICAL CHEMISTRY.

1. Any substance on the earth may be the object of a chemical analysis, and might, therefore, be supposed to contain any of the 57 elements, which at present are known to constitute the earth. To examine it particularly, for all of them, would, in most cases, be either too laborious or impracticable, nor would it be possible to lay down any systematic course, by which the presence of every one of these elements, or their known combinations, could be discovered or disproved. Nor is this necessary. Some of the elements are of the rarest occurrence, and these, as well as a number of the others, only occur in certain combinations, and in company with certain others. The chemist must, in his examinations, be guided by his judgment, and from the origin of the substance, or from its external character, or from the discovery of one or more ingredients in it, form his judgment as to what others he will be most likely to meet with in it, and what not. He must, therefore, first inquire into its origin, and examine carefully its physical properties, and assist his senses, in this examination, by a microscope. Should he, by any of these means, discover it to be a mixture of several different substances, he should try to separate them by dissection or other mechanical means, and examine them separately.

As all substances may be referred to a mineral, or to a vegetable or animal origin, so these two classes of substances show a decided difference in their composition, and require a different method of analysis; hence, it will be proper to treat separately of the analysis of inorganic or mineral substances, and of those of organic origin.

2. Whether a substance be wholly or partly of organic origin, is easily ascertained by heating a portion of it in a glass tube, sealed at its lower end. The presence of organic substances is then manifested, by the combustibility and odor of the gases which they give off, and by the cotemporaneous charring of the heated mass, if not volatile. The odor or reaction of the vapor with turmeric or litmus paper, may also be a guide to discover whether it be of vegetable or animal composition; nitrogenized substances yielding, by their charring, ammoniacal vapors, while those containing no nitrogen, as most vegetable sub-

stances, yielding acid vapors. Care must, of course, be taken not to be misled by the presence of inorganic volatile substances. If the presence of organic matter be evinced, another, or the same portion, is heated in free air to burn away the organic substance, and ascertain whether any inorganic substance be mingled with it. Most organic substances leave some inorganic matter as ashes behind, but some practice will easily enable us to judge, from its quantity, whether it may be considered merely as ash from the organic substance, or to form an essential inorganic ingredient, combined or mixed with it. In the latter case, so much of the substance is incinerated as to leave a sufficient quantity of it to be analyzed alone; the mixture itself is then subsequently examined for determining the organic ingredients, with a due regard to the presence of the inorganic already discovered.

I. ANALYSIS OF INORGANIC SUBSTANCES.

A. Analytical Operations and Manipulations.

3. *Crushing and Pulverization.* When the substance under examination is presented to us in pieces, and is not very soluble, it always requires to be *reduced to powder* before subjecting it to analysis. Small pieces or fragments are first chipped off with a hammer, and then crushed either by wrapping them in paper and striking them on an anvil, or, still better, by introducing them into a steel mortar. (fig. 8.)

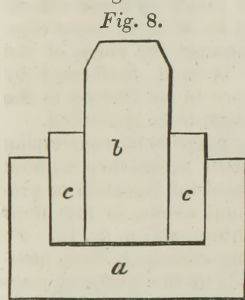


Fig. 8.

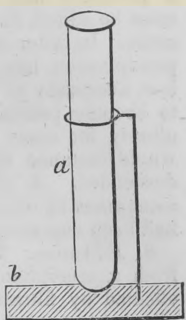
This consists of a low, cylindrical piece of hardened cast-steel, *a*, with a cylindrical chamber. The pestle, *b*, is also of hardened steel, and surrounded by a ring of iron, *c*, in which it slides easily, and which again fits the chamber of the mortar. The fragments are crushed

by blows on the pestle with a hammer. The use of the ring is to prevent particles of the substance from flying about, and also to give it room to expand below, and thereby prevent it from being compressed into a hard mass. The substance is then reduced to a fine powder, by careful *pulverization* in an agate or porcelain mortar, and kept for analysis in a well-corked and labelled bottle.

4. *Weighing.* The balance employed for analytical purposes (see BALANCE) ought not only to turn readily by a small weight when moderately loaded, but also to give the same result on weighing the same thing several times in succession, after removing it, as well as the weights, and returning them again to the same pans of the balance. The arms ought also to be of the same length; this is, however, of no consequence, if it be always remembered to use the weights in one and the same pan, and the substance to be weighed in the other, and, consequently, during an analysis, not to introduce the weights into the latter pan. It is well to have two pans on one side, one for

the reception of the weights, and another above for counterpoises. The weights ought always to be subdivided after the decimal system, so that 10 of the smaller weights will make one of the next higher class. It is then indifferent, whether they be grain weights or French gramme weights. For ordinary purposes, a certain portion of the substance may be weighed out for analysis on a counterpoised piece of glazed letter paper, or a watch-glass; but if it be very hygroscopic, it is necessary to perform the weighing in a narrow glass tube (*a*, fig. 9), in which the substance is prevented from attracting moisture, on account of the difficulty with which the air circulates in it. The tube is kept upright on the stand, *b*, which may be made of cork and a piece of wire. A platinum or porcelain crucible, with a well-fitting cover, answers equally well. Either the tube, with its stand, or the crucible, is counterpoised, a quantity estimated to be sufficient is introduced, and then the exact weight of it ascertained. If, on shaking the substance out, any particle should remain adhering, it must be loosened by gentle tapping, or the vessel returned to the balance, and its weight ascertained and deducted.

Fig. 9.



5. *Digestion. Solution.* In order to effect a complete or partial solution of a substance, the process of *digestion*, particularly with acids, is often resorted to. Solution or digestion is conveniently performed in bell-shaped glass vessels of the annexed form. (Fig. 10.) They ought to be made of glass free from lead, and resist the action of acids on them. They ought also to be thin at the bottom, and well annealed to stand the heat without danger of cracking. The substance is shaken into the bell-glass, the solvent or the

acid added, and the powder mixed up well with it, by a whirling motion of the vessel with the hand. The vessel is then covered by a watch-glass (for which purpose such should be selected as are not attacked by acids), with the concavity downward, to allow the condensing vapors to drop down again into the vessel, and this placed on a sand-bath or wire-gauze (17), at a greater or less distance from the fire, according to the heat required for the digestion. The digestion is in this way carried on till the desired solution or decomposition has taken place.

Fig. 10.



6. *Boiling.* Ebullition or boiling is generally performed in porcelain capsules, of various sizes, and of the annexed shape. (Fig. 11.)

The German are preferable to the French, especially those from the Royal Porcelain Establishment at Berlin, from their resisting sudden changes of temperature more effectually.

Fig. 11.



ally. They are used over the open fire, whether charcoal or the flame of gas, or of the argand spirit-lamp.

7. *Precipitation.* If a solution is to be precipitated, it ought, if no other consideration prevent, to be heated on the sand-bath, or otherwise, before adding the precipitant. The precipitation is conveniently performed in the bell-glasses used for digestion. The precipitant is added during continual stirring with a glass rod, as long as any precipitation is observed. The liquid is then left in a lukewarm place to settle, and, when sufficiently clear, a drop of the precipitant is made to pass through it; if it produces any further precipitation, more must be added, and the liquid again allowed to settle. In order to be perfectly certain that the precipitation has been effectually completed, it is necessary to allow the supernatant liquid to become perfectly transparent, and observe closely for some time, against the light, the whole distance through which the last drop descended. A slight cloudiness may then sometimes be observed, when the precipitation had been considered as already completed.

8. *Filtration.* The separation of a liquid from a precipitate or an insoluble residue, is effected by filtration, by which the liquid is allowed to pass through a paper, supported on a funnel, while the precipitate or insoluble residue is retained by it. The process of filtration is, perhaps, the most important in quantitative analysis; and as the accuracy of many analytical results depend entirely on its successful performance, the means to secure this ought to be thoroughly understood. Much depends, in the first place, on the shape of the *funnel*. It ought to be of glass, and made expressly for the purpose. Where the sides are not straight, and the wider part, therefore, not truly conical, it ought to be rejected, it being impossible to fit a filter properly into it. It is most convenient to have its sides forming an angle with each other of 60° , on account of the great facility it affords in fitting the filter into it. Funnels, whose sides form a somewhat greater or smaller angle, are, however, unobjectionable. A slight rounding off of the angle, where the conical part joins the neck, will be found to accelerate the filtration considerably. The neck ought to be so wide as not to exercise any capillary action, and may, therefore, be broken off obliquely, a few inches below the conical part, so as to terminate in an obtuse point, as indicated in fig. 17, and thereby retain, by adhesion, the smallest possible quantity of liquid. Good filtering paper is perfectly indispensable; it ought to be free from impurities, filter quickly and readily, without allowing the finer precipitates to pass through it, and only leave a small amount of ashes when incinerated. The ashes ought not to exceed 1 per cent. of the weight of the paper. The paper is made into *filters*, by cutting it into circular pieces of different sizes, after patterns of tin. When a filtration is to be performed, one of these filters of the proper size is selected (fig. 12), and then doubled over one of its diameters (*a b*, Figs. 12 and 13), and then over the radius (*c e*, Figs. 13 and 14) perpendicular to the first diameter, so as to form a quadrant. One of

Fig. 12.

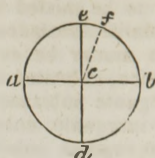


Fig. 13.

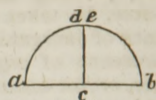


Fig. 14.

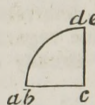


Fig. 15.

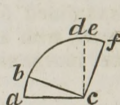


Fig. 16.

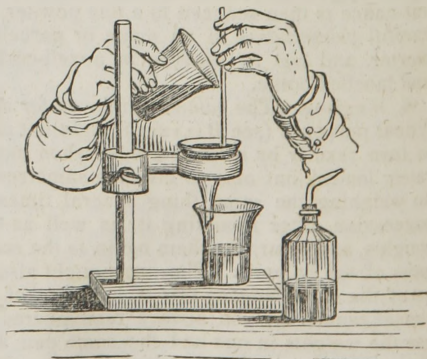


the folds is then opened, forming a hollow cone, as represented in fig. 16, which will fit accurately in the funnel, if the sides of the latter form an angle of 60° . If the angle be greater or smaller, it is necessary to double the filter the second time over another radius (*c f*, Figs. 12 and 15), not perpendicular to the first

diameter, and then open the large or small fold (*a c f*, or *b c f*, Fig. 15), according to the angle of the funnel, and this repeated until a coincidence of the filter with the inside of the funnel is effected. The filter is then moistened with water, for the sake of retaining it in its place, and to prevent it from imbibing, subsequently, the first portions of the filtering liquid, with such avidity as to have its pores choked up by the precipitate. A filter, properly adjusted, ought never to reach up to the rim of the funnel, and should lie with its upper edge close, at all points, against the sides of the glass. The filtration is then performed by transferring the mixture to be filtered to the filter, in the manner about to be described.

9. *Pouring.* For the purpose of transferring a liquid from one vessel to another without loss, the bell-glasses used for digestion or precipitation are spread out above, so that their upper rim forms a continuous lip, fig. 10. To prevent the liquid more effectually from passing down on the outside of the glass, by *pouring* over the edge, the latter may be slightly greased on the outside, at the place where the liquid is to pass over it. A glass rod (see Fig. 17) is then pressed gently with the left hand,

Fig. 17.



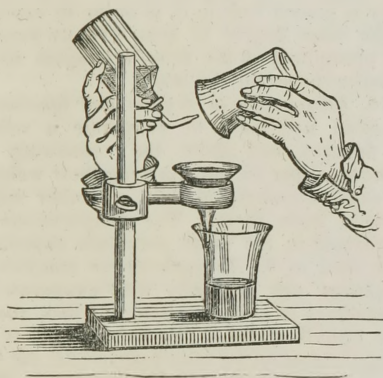
at a right angle, against the edge of the glass held in the right hand, and the liquid allowed,

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by inclining the glass, to pass over the edge along the rod into the other vessel. When the pouring is stopped, care should be taken not to spill the drop adhering to the glass rod. The last portion adhering to the glass rod, and the inside of the vessel, is generally removed by washing with a small portion of pure water, which is added to the main liquid.

10. In transferring a liquid with its precipitate to the filter, care should be taken not to allow the first portion of the liquid to drop from the rod to the bottom of the filter, but on the sides, otherwise a splashing will unavoidably occur. A filter ought never to be filled with the liquid to its upper edge, still less ought the accumulating precipitate be suffered to reach that point. If this threatens to be the case, the rest must be thrown on a new filter. As soon as all the liquid, and as much of the precipitate as will follow it, has been thrown on the filter, the portion remaining in the glass and adhering to the glass rod is washed down into one heap at the bottom of the glass by the jet of the syringe-bottle (11); and when this also has been thrown on the filter, the portion that still remains is washed down on the filter by the syringe-bottle, holding the glass over the filter in an inclined position, with the mouth downwards, as represented in *fig. 18*. Should some of the precipitate adhere

Fig. 18.



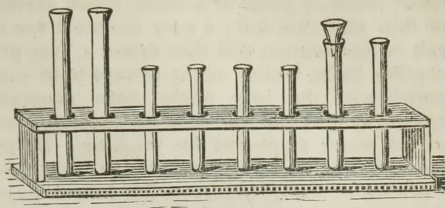
so firmly to the sides of the vessel that it cannot be removed by the jet of the syringe bottle, it may first be loosened by the end of a feather.

11. The syringe-bottle consists of an ordinary 6 or 8 oz. vial, into the mouth of which is adapted, by the aid of a perforated cork, a short glass tube, drawn out at its extremity to a point with a small orifice, and slightly curved in the middle. (*Fig. 17*.) The bottle is half filled with water, and, by blowing into it through the orifice, the air in the bottle is compressed, and if the bottle be now quickly inverted, *fig. 18*, the water is forced out of the orifice of the tube in a small jet, which may be applied to any desired place.

12. In *qualitative analysis*, the processes of *solution*, *digestion*, *boiling*, and *precipitation*, are generally performed on a smaller scale, for which purpose test-tubes of different sizes are conveniently employed. (*Fig. 19*.) They are made of moderately thin glass tubes, sealed at their lower end, and turned slightly outward at

ANALYSIS.

Fig. 19.



their upper edge. Heat is applied directly to the sealed end by the aid of a spirit-lamp with a single wick (*Fig. 20*), while the test-tube is held at the other

Fig. 20.

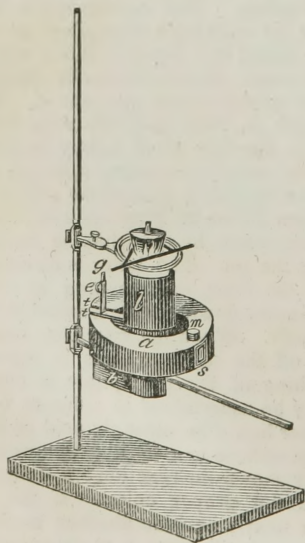
extremity in an inclined position, either by the fingers, or, if it becomes too hot, by a doubled slip of writing-paper twisted round it. It is sometimes convenient to close the orifice by the end of the first finger, to prevent the liquid from being thrown out by any sudden ebullition. A few test-tubes of a larger size are used for carrying on the operations with the main liquid, while smaller ones are employed for the application of special tests to smaller portions of it. The latter may in many cases be done on a still smaller scale, and often with as much certainty, with a few drops of the liquid transferred to a glass pane by the extremity of a glass rod. One or two drops of the test is in the same way transferred to the pane next to the liquid, and then both are made to mix by the rod or by inclining or shaking the pane. *Filtration* is performed by small funnels, or sometimes without the aid of funnels, through small filters adjusted in the upper end of the test-tube, giving one side of the filter a bend inwards to leave an open passage for the air out of the tube.

13. *Washing*. The syringe-bottle is indispensable for washing a precipitate on the filter after the liquid has drained off, for which purpose hot water should always be employed, if no other consideration prevent it. The syringe-bottle is filled half-full with water, the cork with the tube fitted tightly in, air blown into it, and then, by inverting it, the jet of water is directed obliquely against the precipitate, so as to loosen it from the filter and mix it thoroughly with the water by the whirling motion produced by the jet. The latter is directed to all parts of the filter, commencing at the upper edge and going downward in a spiral to the level of the water. When the water has completely drained off, the same process is repeated till the washing of the precipitate is completed. This may be ascertained in different ways. If the mother liquid be strongly acid or alkaline, it usually suffices to continue the washing till the water shows no reaction on delicate test-paper of the proper color. If the mother liquid be nearly neutral, another mode, applicable in nearly all cases, is to evaporate to dry-

ness a few drops of the last washings on a small piece of glass or a small clean surface of thin platinum foil; a very minute trace of salt in the solution will then cause a very perceptible stain, which ought always to be compared with the very slight stain generally caused by the evaporation of an equal quantity of the water employed for washing. During the filtration, as well as during the subsequent washing of the precipitate, the funnel ought to be kept covered with a glass pane to prevent evaporation and concentration, or even deposition of the salts in solution on the upper edge of the filter.

14. *Drying, ignition, weighing of precipitates.* If the precipitate on the filter is to be weighed, the latter is loosened from the funnel after completing the washing, and received on folds of blotting-paper to absorb the greater part of the water. The precipitate is then dried on the filter either in a water-bath or in a lukewarm place. If the precipitate is such as to suffer no change by ignition, the filter with the dry precipitate is transferred into a small platinum crucible, or if the precipitate contains any easily reducible metal or other substance that would corrode platinum, into a porcelain crucible. For greater security against loss by the transfer, it is advisable to place the crucible on a piece of glazed letter-paper. The mouth of the filter is introduced into the crucible, and the contents carefully worked out by rubbing the sides against each other. Without withdrawing the mouth from the crucible, the filter is then folded up and placed loosely on top of the precipitate. Another method frequently applicable is to grasp the upper edge of the filter by a pair of forceps, after having folded it so as to be narrower than the mouth of the crucible, and then ignite it at its lower extremity, allowing its contents to drop into the crucible as the filter gradually burns away. The crucible with its contents is afterwards heated over the gas, or an argand spirit-lamp (Fig. 21), at first cautiously keeping the cover

Fig. 21.



on, if any loss from decrepitation of the precipitate be apprehended. When the filter has become completely charred, the heat is raised gradually to ignition, while the cover is partly or wholly removed, and the air admitted freely into the crucible for the complete incineration of the filter, which is effected by placing it in an inclined position, allowing its mouth to reach beyond the ascending current of hot air, which contains little or no oxygen. It sometimes, however, becomes necessary to stir the precipitate with a little platinum spatula, and to increase the heat of the flame by throwing a jet of air through it, either by a large mouth-blowpipe, or by the jet of a table-blowpipe. As soon as complete incineration of the filter is effected, the crucible is removed and left to cool with the cover on, and weighed. The crucible having been previously ignited and counterpoised, the weight of its contents is easily ascertained, from which is deducted the known weight of the ashes of the filter, previously determined by the incineration of filters of different sizes.

15. If, on the contrary, the precipitate be of such a nature as not to stand the ignition necessary for incinerating the filter, it becomes necessary to weigh it on the latter, which must then be counterpoised previous to filtration by another filter of the same paper. When subsequently drying the precipitate on the filter at the requisite temperature, the counterpoise filter is placed next to it, in order to expose it to the same degree of heat. While weighing the precipitate on the filter, it is again used as a counterpoise for the latter.

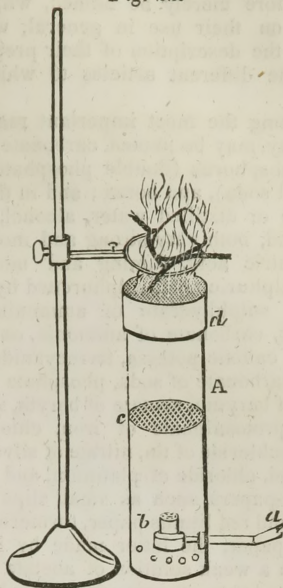
16. *Evaporation to dryness and ignition.* It is often necessary to evaporate a solution to dryness, and ignite the remaining substances, either for ascertaining their weight or to expel ammoniacal salts or other volatile matters from them. The evaporations are performed in the same porcelain capsules as described in 6. In quantitative analysis, the washings are generally first evaporated by themselves to concentration, and then the mother liquids added. The evaporation is performed either on the sand-bath or over the flame of gas or of the argand spirit-lamp. When the solution is so concentrated as to commence drying, a spirting is very apt to take place, and can only be prevented by moderating the heat and stirring the mass continually with a glass rod; or by finishing the evaporation when it approaches this point in a water-bath, by placing the capsule on top of a pan or other vessel in which water is kept boiling. Another very efficacious method to avoid the spirting over the spirit-lamp, is to interpose a small circular metallic plate, either of thin sheet-iron or of platinum, between the flame of the lamp and the bottom of the capsule, without touching the latter. As soon as the mass has become perfectly dry, it is to be transferred to a platinum or porcelain crucible to be ignited. It is a difficult matter to make this transfer effectually and without loss. The best method is to allow the mass to cool, and then to moisten it with two or three drops of water, barely enough to allow it to be loosened from the capsule by a small spatula, and then to transfer it as com-

pletely as possible into the crucible placed on a sheet of glazed letter-paper. The particles remaining on the spatula and in the capsule are then washed down in the corner of the capsule by a few drops of water, and there again evaporated with caution to dryness and transferred in the same way. The introduction of so much water in the latter as to cause a spitting of the mass by a subsequent heating ought to be carefully avoided. The mass is then heated gradually in the crucible over the spirit-lamp to the desired temperature. If it be desired to weigh it, the crucible ought of course to have been previously counterpoised, and to be left covered while cooling.

17. Gas-light being at present introduced in most of the larger cities, great facilities are afforded by it for the performance of analytical operations. Having an argand gas-burner, with a short chimney of sheet-iron or copper, attached to a flexible leaden tube, and the other end of the latter connected with the gas-pipe, by means of a stop-cock, the flame of the argand burner may be applied to any vessel, supported in the same manner, and on a similar stand, as that on which the argand spirit-lamp, with its appurtenances, is mounted. It is only necessary to prevent the deposition of carbon on the vessel, by turning off the gas stop-cock, till the flame ceases to deposit any carbon on it. Sufficient heat is in this way obtained for evaporation and ebullition in capsules, &c. Even the different operations of drying or digesting in bell-glasses (5), or heating water in the syringe-bottle, may be performed with perfect safety, by turning the flame of the gas-burner sufficiently low, and not exposing the vessels to its immediate action, but placing them on a piece of fine wire-gauze. The ignition of precipitates in a crucible may also be effected, by using the mouth-blowpipe for throwing a jet of air through the middle of the burner, sufficient to cause the complete combustion of the gas. For the latter purpose, however, it is preferable to employ a larger argand burner, fixed over the jet of the table-blowpipe. See *Table-Blowpipe*. A much greater heat may, in this way, be procured, than by the argand spirit-lamp, and it enables the operator to dispense almost entirely with furnace fires.

Another method of employing the heat of burning gas, so as to avoid entirely the deposition of carbon, is to mingle it with atmospheric air previous to its ignition, which may be readily accomplished, by an arrangement similar to that in *fig. 22*. A is a cylinder of sheet-iron, over the top of which fine wire-gauze is stretched, and a ring of sheet-iron, *d*, a little larger than the cylinder, is pressed over it; to prevent the wear of the gauze, a layer of coarse gravel may be strewed over it. Around the lower part of the cylinder a series of holes is punched to admit the air, and at *c* a coarse wire-gauze is introduced to mingle the gas and air more thoroughly. The stop-cock being turned, the gas enters through the gas-pipe, *a*, terminating in an argand burner, *b*, whence it issues and mingles with the air, which is drawn in through

Fig. 22.



the openings below by the upward current of gas; the mixture passing through the fine wire-gauze at the top, is there inflamed, and should burn with a bluish flame. Where the quantity of gas is too great for the amount of air admitted, the flame will be white and smoky, but by regulating the supply of gas, the due proportion for a blue flame may be easily attained. Now, to obtain a blue flame from a cylinder of large diameter, a considerable quantity of gas will be requisite, and hence an economical advantage is gained by employing cylinders of different diameters. In the same cylinder also, where different quantities of heat are desired, the lower series of holes may be made large, and a ring of sheet-iron slid over them, by which the quantity of air admitted may be regulated according to the quantity of gas consumed. The cylinders may be $2\frac{1}{2}$ to 5 inches diameter by 6—8 inches in height; but by introducing several pieces of coarse gauze, *c*, at short distances apart, the height may be diminished. The highest amount of heat produced by this apparatus is a cherry-red by daylight. For burning off filters in a platinum crucible, a cylinder of $2\frac{1}{2}$ inches diameter is amply sufficient; but for heating larger vessels, such as capsules, those of 4—5 inches diameter are desirable. This mode of burning the gas presents the advantages of producing any degree of heat as high as a red, of not blackening vessels immersed in the flame, and of avoiding, with more certainty, the fracture of porcelain or glass vessels, from the diffusive character of the flame.

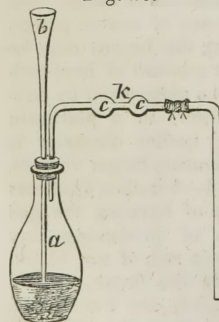
18. Besides the glasses and apparatus mentioned in the preceding paragraphs, several smaller articles are made use of, such as forceps for handling the crucibles, small platinum spatulas, a forceps with platinum points, &c.; but it would exceed the limits of this article to give a detailed description of them. The same remarks apply to the reagents and their preparation. Some of the most important

will therefore merely be named, with a few remarks on their use in general, while we refer for the description of their preparation, &c., to the different articles to which they belong.

19. Among the most important reagents in the dry way, may be named, carbonate of soda, salt of phosphorus (double phosphate of ammonia and soda), and borax; and in the moist way, pure or distilled water, alcohol, chlorohydric acid, both very strong and moderately diluted, nitric acid, fuming and moderately diluted, sulphuric acid, sulphuretted hydrogen, ammonia, sulphhydrate of ammonium, sal-ammoniac, carbonate of ammonia, oxalate of ammonia, caustic potassa, ferrocyanide of potassium, carbonate of soda, phosphate of soda, chloride of baryum, acetate of baryta, sulphate of lime, protosulphate of iron, chloride of lead, protochloride of tin, nitrate of silver, chloride of gold, chloride of platinum, and the different test-papers, such as small slips of delicate blue and red litmus paper, turmeric paper, and lead paper, the latter made by imbuing paper with a weak solution of acetate of lead. Most of the latter reagents are either liquid or used in solutions, which ought to be concentrated, and of uniform strength. They are best kept in stoppered glass bottles. In pouring out the reagents, the neck of the bottle ought never to be allowed to touch the edge of the vessel containing the liquid to be tested, but the last drop adhering to the flange of the neck returned to the bottle by the stopper; the latter should not be placed on the table, but on a clean pane of glass. After using a reagent it is, in many cases, necessary to wipe the stopper and the inside of the neck of the bottle.

20. As sulphuretted hydrogen is but sparingly soluble in water, and apt to spoil by keeping, it should always be applied in its gaseous state, by passing a current of the gas through the liquid to be tested or precipitated by it. Fig. 23 represents the form of the apparatus which

Fig. 23.



we employ for this purpose: *a* is the bottle containing sulphuret of iron, from which the gas is evolved, by pouring first water and then sulphuric acid on it, through the funnel-tube *b*. A loose plug of cotton is thrust into the exit tube at *k*, between the two bulbs *cc*, to retain solid particles carried over mechanically, while the bulbs receiving the condensed moisture prevent it from choking the tube. Another tube, bent at right angles, is connected with the exit-tube by a caoutchouc joint, as seen in the figure, the end of which is introduced into the liquid through which the gas is to be passed. Instead of the bottle *a*, with the funnel-tube *b*, a simple 8 oz. vial, without the funnel-tube, and having a cork, with a single perforation, for the exit-tube, will, in most cases, answer equally well.

B. ANALYSIS OF SOLID INORGANIC SUBSTANCES.

1. Qualitative Analysis of Solids.

21. *Preliminary Examination.* We first endeavor to arrive at some general conclusion in regard to the chemical nature and composition of the substance under examination, from the history of its origin or from its external characters. The origin of a substance will often inform us whether it be a mineral or an artificial production. In the former case, the locality or the association of other minerals with which it occurs will, in many instances, assist us to form an opinion in regard to its composition; the same will be the case if it be an artificial production, either accidental or designed in pharmacy or in the arts, as it may tell us what particular substances have been present or employed in its production. If its history does not lead to any such conclusion, an examination of its external characters will afford it: such as colour, lustre, form of aggregation, hardness, specific gravity, taste, odor, &c. We shall thus be enabled to decide whether it be a metallic body, being perfectly opaque and having a metallic streak, or a body of non-metallic properties, being saline, vitreous, or earthy, either massive, pulverulent, or crystalline, &c. This will be still more evident when we proceed to the *preliminary examination in the dry way*. For this purpose we introduce a portion of it into a small glass tube, sealed at its lower end, where the substance is placed, and then heated by a small spirit-lamp, first alone and subsequently increasing the heat by the aid of the blowpipe. If it contain any volatile substances, such as chemically combined water, &c., these will condense in the upper and colder part of the tube. By the odor, and by small pieces of litmus and turmeric paper held in the mouth of the tube, we are enabled to discover acid or alkaline vapors, &c. The fusibility and other behavior of the mass is also to be noticed. Another portion is next heated with free access of the air, or roasted, by placing it in a glass tube open at both ends, and heating slowly the place where the substance is lying by a spirit-lamp, as in the former case, while the tube is held in an inclined position. All combustible substances are then oxidized by the current of air passing over the heated mass. We notice particularly whether any odor of sulphurous acid be perceived at either of the ends of the tube, which indicates the presence of sulphur or a metallic sulphuret. We may also observe whether it yields a ring of a sublimate at some distance above it, and whether the sublimate be volatile on the application of heat, and whether it thereby disappears or may gradually be driven higher up the tube without disappearing. But as these tests and many others of the same kind, which will enable the operator to discover a number of substances, and may be instituted at this period of the examination, will be described in detail under the article *BLOWPIPE*, we will here merely mention that not only the two above-mentioned tests ought never to be omitted, but that a portion

of the substance, both in its original state and particularly after thorough roasting, ought also to be tested on charcoal before the blowpipe with its three principal tests, viz. with carbonate of soda for reducible metals, with borax for coloring and other substances, and with salt of phosphorus both for the latter purpose and especially for the discovery of silicic acid or a silicate, in which it is indispensable. If the substance therefore be non-metallic, and when added in very minute fragments or in powder to a clear bead of salt of phosphorus, leaves behind a white spongy or flaky mass, floating about in the ignited bead without signs of solution, we may infer the presence of silicic acid or a silicate. Having thus decided by preliminary examination whether the substance under examination be a metallic body or a sulphuret of metals, or a non-metallic substance, either saline, vitreous, or earthy (but no silicate), or a silicate, we next proceed to the main qualitative examination in the moist way.

a. Qualitative Analysis of Metals or Alloys.

22. For the sake of avoiding too great complexity, we shall omit the consideration of those metals which are of rarer occurrence, and suppose only the following to be present, as occurring most frequently in nature, and constituting the greatest part of the alloys met with in common life, viz. 1. copper, 2. lead, 3. silver, 4. mercury, 5. bismuth, 6. arsenic, 7. antimony, 8. tin, 9. gold, 10. iron, 11. zinc, 12. nickel.

23. The metal or alloy is reduced to small pieces, or, still better, to a powder, by crushing it in the steel mortar (3), if brittle, or to filings by a sharp and clean file, if ductile, and then treated with nitric acid of moderate strength by the aid of heat, either in a small bell-glass, (5) or a larger test-tube (12), as long as any action takes place, and either complete solution is effected, or a residue remains on which no further action is perceptible, even by a fresh portion of acid or by the addition of water. If no residue remains, it proves the absence of gold, antimony, and tin. If, on the contrary, a residue remain, it may contain these three metals. (It may be remarked that if the alloy contain silver, and the nitric acid is not perfectly free from chlorohydric, chloride of silver will remain undissolved as a white, rather flocculent residue, which is soluble in caustic ammonia.) The residue is separated from the solution by filtration, and washed thoroughly by the syringe-bottle on the filter (13). Of the three metals just named, gold is not acted on by pure nitric acid, and will therefore, if present, remain in its metallic state, but often so finely divided as to constitute a black powder, which, by friction with a burnisher, yields a metallic streak, and dissolves easily in chlorohydric acid with the addition of a small portion of nitric; the solution, by the addition of dissolved sulphate of the protoxide of iron, again yields a yellow or dark precipitate of metallic gold. Tin and antimony are converted into their oxides by the action of nitric acid, but being insoluble in the acid, they remain as a white powder. To distinguish these two, the residue is digested with a strong solution of

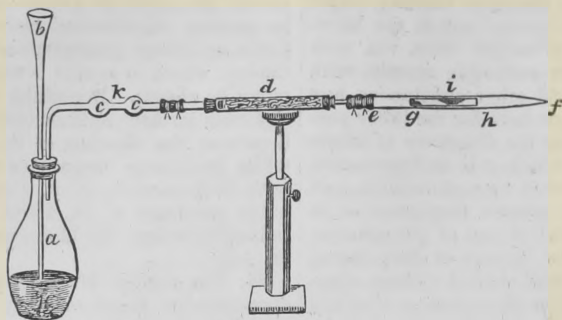
tartaric acid or bitartrate of potash, which dissolves the oxide of antimony, if present, and by passing sulphuretted hydrogen through it, yields an orange precipitate of sulphuret of antimony, which of course is not obtained if antimony be absent. If nothing is left after digestion with tartaric acid or bitartrate of potassa, it proves the absence of tin. If, however, a white precipitate remain even after digestion with fresh portions of it, it indicates the probable presence of tin, which is confirmed by reduction before the blowpipe with carbonate of soda.

24. The original filtered solution obtained by digesting the metal or alloy with nitric acid, may contain all the metals named above (22), with the exception of gold, tin, and antimony, of which last it may also contain traces; if it exist in the alloy (23). A small portion of the solution is then mixed with a large quantity of water. If a milkiness be produced, it is caused by the precipitation of basic nitrate of bismuth, and indicates the presence of this metal. The remainder of the solution is diluted with some water, and a current of sulphuretted hydrogen passed through it for some time, till after stirring, it distinctly retains the smell of sulphuretted hydrogen and blackens a small strip of lead paper (19) dipped into it. If no precipitate be produced, none of the 6 first enumerated metals are present.

25. If it should yield a very fine and light powdery precipitate of a white color, this may arise from the oxidation of the sulphuretted hydrogen, and consists then only of sulphur, which may be ascertained by collecting and washing it on a filter, and when dry roasting it in an open glass tube as described above (21). If it only consist of sulphur, it will burn away and partly volatilize by the heat, which latter portion also by being chased higher up in the tube oxidizes and disappears entirely. If it should contain some sulphuret of arsenic, a white sublimate of arsenious acid is formed higher up in the tube, which may be volatilized by heat, but does not disappear. If it be suspected to contain arsenic, it must be tested as prescribed in the next paragraph. If the alloy were found to contain antimony, traces of the latter dissolve in the nitric acid, and are precipitated by the sulphuretted hydrogen as sulphuret of antimony. In this case the precipitate has a decided orange tint, and yields by roasting in the open tube a ring just above the place where it is heated, of a white sublimate, which is not volatile.

26. If a precipitate be formed by sulphuretted hydrogen of a pure yellow color, it is caused by the precipitation of arsenic as sulphuret of arsenic. To ascertain the existence of the latter in it, the precipitate is filtered and washed, and then mixed in its moist state with from 3 to 4 parts of carbonate of soda, and the mixture introduced into one end, *g*, of a small glass tube (*g, h*, fig. 24), but so as to allow a passage over it, and this smaller tube again introduced into a larger one *c f*, drawn out at one extremity, the other end, after the introduction of the smaller tube, being connected with an apparatus for generating hydrogen. Fig. 24 exhibits the whole apparatus. *a* is the evolu-

Fig. 24.



tion flask in which the hydrogen is generated from granulated zinc and dilute sulphuric acid poured into it through the funnel tube, *b*. *d* is a tube containing chloride of calcium for the desiccation of the gas by its passage through it, which is necessary for the detection of minute portions of arsenic; for ordinary purposes it may be omitted, and instead of the flask with the funnel tube, an ordinary 8 oz. vial, into which the zinc and sulphuric acid are introduced at once, will in many cases answer the purpose. After a current of hydrogen gas has been established through the tube, the part at *g*, where the end of the little tube which contains the mixture is situated, is heated by a spirit-lamp, at first gently, in order to expel all moisture, but then suddenly to a red heat. If any arsenic be contained in the mixture, it is reduced and condenses at *i* as a black metallic spot or ring. If the tube be then taken out, broken off at the ring, and heated, the characteristic garlic odor of arsenic is perceived, while the metallic ring disappears.

27. If a precipitate be produced by sulphuretted hydrogen of a dark color, it contains the sulphurets of some of the metals from 1—5, and may besides contain sulphuret of arsenic with traces of sulphuret of antimony, if this latter has been found in the alloy. The precipitate is separated, as quickly as possible, by filtration, and as soon as the liquid has passed through the filter, it is removed, and the washwater from the subsequent washing of the precipitate on the filter with hot water, by aid of the syringe-bottle, is not mixed with it. It is then scraped from the filter and heated in a small digesting glass, covered with a glass plate, or in a large test-tube with a solution of sulphhydrate of ammonium, which dissolves the sulphurets of arsenic and antimony. The solution is filtered under cover of a glass plate from the remaining black precipitate, and removed from under the funnel as soon as it has passed through. The precipitate is washed if possible with hot water, to which has been added a few drops of sulphhydrate of ammonium. The filtered solution is mixed with dilute chlorohydric acid until it is slightly acid. If the solution thereby merely becomes milky from a precipitate of a whitish color and of a light pulverulent appearance, the latter consists only of sulphur; if it be yellow, it consists of arsenic; if the alloy contained antimony, it will have an orange tint from a small portion of sulphuret of antimony. It is tested for arsenic as described above (26).

28. The washed sulphurets remaining on the filter, which may contain all the metals from 1—5, are scraped off the filter, and heated in a small porcelain capsule with moderately strong nitric acid. This dissolves it with separation of yellow flocculent sulphur. If it, or at least a portion of it, should remain of a black color without dissolving, even by boiling, it probably consists of sulphuret of mercury. To ascertain this, separate it by filtration, and wash, dry, and roast it in an open glass tube; it then yields a gray metallic ring, which, when touched with an iron wire, collects in small globules of metallic mercury. If lead was contained in the precipitate, a portion of it would, by the oxidation with nitric acid, be converted into sulphate of lead, and be mixed with the separated sulphur, as a heavy white powder, but the greater part will dissolve in the nitric acid. Add, therefore, to a portion of the filtered solution, sulphuric acid; if it produces a heavy, white, pulverulent precipitation, it indicates the presence of lead. To another portion of the filtered solution, add chlorohydric acid; if it produces a white flocculent precipitate, which does not disappear by the addition of much water, but is soluble in caustic ammonia, it is chloride of silver, and indicates the presence of this metal in the solution. If ammonia, added to another portion, produces a deep blue color, the presence of copper is indicated. The presence of bismuth will already have been detected (24), but may also now be exhibited, by a white precipitate, upon the admixture of a large quantity of water.

29. The original solution which has been filtered from the precipitate, caused by sulphuretted hydrogen, can then only contain the three metals 10—12. To discover whether any of these be present, neutralize a small portion of it with ammonia, and then add sulphhydrate of ammonium. If no precipitate be produced, none of these metals can be present. If a white precipitate be produced, it only contains zinc. Iron yields, with this reagent, a black or greenish black, and nickel a brownish black precipitate. In the two latter cases a white precipitate of zinc could not be distinguished. The main portion of the solution is boiled, with the addition of nitric acid, and filtered; ammonia is then added till it affords an alkaline reaction. If it cause a reddish or brownish flocculent precipitate of peroxide of iron, the presence of this metal is indicated. For

further confirmation, dissolve it, after filtration and washing, in chlorohydric acid, and mix it with ferrocyanide of iron, which then will produce a deep blue precipitate of Prussian blue. If the solution filtered from the peroxide of iron have a greenish color, and, when mixed with caustic potassa, yield a light green precipitate, this indicates the presence of nickel. For farther confirmation, separate it by filtration, and reduce it by carbonate of soda before the blowpipe, when it will yield metallic spangles of nickel of a silver-white color. To the filtered potassic solution add sulphhydrate of ammonium. If zinc be present, it is then indicated by a white precipitate of sulphuret of zinc.

b. Qualitative Analysis of Sulphurets of the Metals proper.

30. The sulphurets which most commonly occur are those of copper, lead, silver, mercury, antimony, arsenic, zinc, and iron; all these sulphurets exhale, when roasted in an open glass tube, the odor of sulphurous acid. As the alloys were mostly artificial products, so the sulphurets are generally native productions. They may be divided into two groups, those having metallic appearance and properties, and those which are non-metallic or vitreous, and therefore often possess more or less translucency on their edges. As instances of the former group, may be named iron and copper pyrites, with the other sulphurets of copper, galena, often argentiferous, sulphuret of antimony, and several compound sulphurets of this latter with other sulphurets. Among the sulphurets of the latter group, may be named blende, or sulphuret of zinc, and sulphuret of arsenic, with some of its compound sulphurets. The sulphuret of mercury occurs rarely in combination with other sulphurets, and is easily distinguished by giving globules of metallic mercury, when roasted in the open tube. The sulphuret of tin is extremely rare in nature; as an artificial production, it constitutes *mosaic gold*. The solution of the above-named sulphurets (with the exception of the sulphuret of mercury) may be effected by nitric acid, either of common strength or the fuming acid. If the former be applied, it is necessary to continue the digestion for some time, in order to decompose it perfectly. The sulphur is hereby partly oxidized to sulphuric acid, and partly separated as sulphur, at first of a gray color, from the admixture of undecomposed sulphuret, but afterwards assuming its natural yellow color. If the sulphuret contain antimony or tin, the oxides of these remain mixed with the sulphur; and if it contain lead, a great portion of the lead also remains mixed with the sulphur as sulphate of lead, but a portion of it is always dissolved in the nitric acid of usual strength. If, however, fuming nitric acid be employed for the solution, more of the sulphur is converted into sulphuric acid, and the whole quantity of lead may then remain as insoluble sulphate of lead. The lead may be discovered in the residue by reduction with carbonate of soda before the blowpipe. As soon as the sul-

phuret is decomposed completely, the solution is diluted with some water, and then filtered, and the examination of it performed exactly as the solution from alloys described in the foregoing. The solution of the sulphurets may also be effected by digestion with aqua regia; but if the sulphuret then contain silver, this metal will remain with the residue as chloride of silver, while most of the antimony is obtained in the solution as chloride of antimony, which, by dilution with a large portion of water, yields an insoluble oxychloride of antimony, and must, therefore, not be confounded with bismuth.

c. Qualitative Analysis of Substances of Non-metallic Appearance, not Silicates.

31. For the sake of avoiding too much complexity, we shall exclude substances of rare occurrence, and confine ourselves to the following more general ingredients of such substances as occur in nature, or are products of the arts and manufactures:

Bases or Metallic Oxides.

- | | | |
|--------------|----------------|---------------|
| 1. Potassa, | 8. Alumina, | 15. Lead, |
| 2. Soda, | 9. Chromium, | 16. Bismuth, |
| 3. Ammonia, | 10. Zinc, | 17. Copper, |
| 4. Baryta, | 11. Manganese, | 18. Silver, |
| 5. Strontia, | 12. Cobalt, | 19. Mercury, |
| 6. Lime, | 13. Nickel, | 20. Gold, |
| 7. Magnesia, | 14. Iron, | 21. Tin, |
| | | 22. Antimony. |

Acids, &c.

- | | | |
|------------------|---------------|---------------|
| 23. Sulphuric, | 27. Boracic, | 31. Chlorine, |
| 24. Nitric, | 28. Carbonic, | 32. Iodine, |
| 25. Phosphoric, | 29. Chromic, | 33. Bromine, |
| 26. } Arsenious, | 30. Chloric, | 34. Fluorine, |
| } Arsenic, | | 35. Sulphur. |

As a great number of artificial productions of this class of substances are either oxides or consist only of one base and one acid, or one of the last simple electro-negative substances, 31—35, combined with a metal of one of the bases, it will be more acceptable to the student first to point out a plan of examination for such substances.

Those consisting only of one Base and one Acid or a Haloid Salt.

32. A portion of the substance is first digested with water, in order to effect its solution in this liquid, if possible. Should it not dissolve readily, it is well to form some idea of its solubility, by evaporating a few drops of the water on a small platinum dish, and observing how much residue it leaves. If the substance should thus prove to dissolve sparingly, or not at all, its solution is attempted by the addition of chlorohydric or nitric acid. The latter is only used when the first either produces a precipitate in the aqueous solution or changes the substance into a white, insoluble precipitate, without dissolving it, in which case, the presence of silver, mercury, or lead may be surmised. If neither of the two acids effect its solution, it may be attempted by a mixture of them both (nitromuriatic acid or aqua regia), choosing rather an excess of chlorohydric acid.

a a. Those soluble in Water, Chlorohydric or Nitric Acid, or Aqua Regia.

33. *Examination for the base*, including arsenious and arsenic acids. If the solution has been effected by water, a few drops of chlorohydric acid, or (if this produces a precipitate) of nitric acid, is added, so as to render it slightly acid. If the solution has been made by one of these acids, it, of course, does not require the addition of acid, but is then diluted with some water, and if this should produce a milkiness, so much more acid again added as is just sufficient to keep it in solution. A current of sulphuretted hydrogen is then passed through the solution till, after thorough stirring, it smells strongly of this gas, and blackens a strip of lead-paper dipped into it. If no precipitate be formed, even after some time, it contains none of the bases, 15—22, nor 26; proceed then as further directed in (36).

34. If a precipitate be formed by sulphuretted hydrogen, which presents a fine, *white, pulverulent* appearance, it then consists only of sulphur, from the decomposition of the sulphuretted hydrogen, and when abundant, is caused by the oxygen of some ingredient in the solution, such as peroxide of iron. To ascertain whether it contain any thing besides sulphur, collect, wash, and roast a portion of it in an open glass tube, as prescribed in (25). If it be found to consist of any thing but sulphur, or, if the precipitate by sulphuretted hydrogen be of any other color than white, separate, and digest a portion of it with a solution of sulphhydrate of ammonium, containing an excess of sulphur. If it dissolve, it contains one of the metals 20—22, or 26. To distinguish these, observe: if the precipitate be of a *yellow* color, it may be produced by peroxide of tin or arsenic; test it for the latter substance, as indicated in (26); if no metallic ring, nor the odor of arsenic be obtained, it is sulphuret of tin; for further proof, roast a portion of it in an open tube, and reduce it to metallic tin before the blowpipe, on charcoal, with carbonate of soda; if the precipitate by sulphuretted hydrogen be of an *orange* color, it indicates the presence of antimony; if it be of a *dark brownish color*, the presence of gold or protoxide of tin may be suspected; roast a portion in an open tube; if it contain the former it will leave metallic gold; if this be not the case, test the roasted portion for tin, by reduction with carbonate of soda, before the blowpipe.

35. If the precipitate by sulphuretted hydrogen do not dissolve in sulphhydrate of ammonium, it contains one of the metals 15—19. To distinguish them, treat it as directed in (28).

36. If sulphuretted hydrogen produce no precipitate in the original solution, or merely a precipitate of sulphur, supersaturate the solution slightly with ammonia, and add sulphhydrate of ammonium. If no precipitate be formed, the solution contains none of the bases 8—14; proceed then further, as directed in (37). If, on the contrary, a precipitate be produced, it may be caused by the presence of any of the bases 8—14, or of the phosphates or fluorides of 4—7. To distinguish these, observe:

a. If the precipitate, by sulphhydrate of ammonium, be of a dark or black color, it indi-

cates the presence of either iron, nickel, or cobalt. Separate it by filtration, and dissolve a portion of it in chlorohydric acid, with the subsequent addition of a few drops of nitric acid, and boil; add, then, ammonia in excess; if the latter produce a red or brownish flocculent precipitate, which, when redissolved in chlorohydric acid, yields a dark blue color, by the addition of ferrocyanide of potassium, the base is *oxide of iron*. If ammonia produces no precipitate, but the subsequent addition of caustic potassa, a light greenish, the base is *oxide of nickel*; for further proof, reduce it, on charcoal, with carbonate of soda, before the blowpipe. If the addition of potassa to the ammoniacal solution, produce no precipitate, but the solution previously exhibited a pink color, it indicates the presence of *cobalt*. Add sulphhydrate of ammonium, roast the precipitate, and produce the blue bead of cobalt, before the blowpipe.

b. If the precipitate be of a flesh color, it indicates the presence of manganese. For further proof, roast it and produce the green color of manganese, by fusion with carbonate of soda and nitre on platinum foil.

c. If the precipitate be of a bluish green, it consists of the hydrated oxide of chromium; for further proof, dissolve it in salt of phosphorus before the blowpipe, and obtain a green bead, retaining its color, both in the oxydizing and reducing flame.

d. If the precipitate be of a white color, it may be either alumina or sulphuret of zinc. If the substance under examination was insoluble in water, it may also be phosphate of alumina, or of some of the alkaline earths, 4—7, or the fluorides of their metallic bases. To ascertain this, redissolve a portion of the precipitate in chlorohydric acid, and add caustic potassa in excess. If the precipitate, which is formed at first, redissolve in the excess of potassa, it indicates the absence of the above phosphates or fluorides. It contains, then, either alumina or zinc. To the solution in caustic potassa add a small portion of sulphhydrate of ammonium; if a white precipitate be produced, it consists of sulphuret of zinc, and indicates the presence of this metal. If no precipitate be produced, supersaturate the solution with chlorohydric acid, and add ammonia in excess; if a white precipitate be then produced, it consists of alumina. If it be desired to ascertain whether this contain phosphoric acid, either resort to the blowpipe test to fuse it with boracic acid and iron wire, or redissolve a portion of it in chlorohydric acid, add tartaric acid, supersaturate with ammonia, and then add a solution of sulphate of magnesia. The formation of a white precipitate of phosphate of magnesia and ammonia, indicates the presence of phosphoric acid.

If the precipitate do not redissolve in the excess of potassa, and especially if the substance under examination were insoluble in water, the presence of a fluoride, or a phosphate of an alkaline earth, 4—7, may be suspected. Test the substance for fluorine, as directed in (45,) and, after complete expulsion of the fluorine by sulphuric acid and heat, dissolve the remaining sulphate, with due regard

to the insolubility of the sulphate of lime, and examine it for the base, as directed in the following (37). If no fluorine be present, test for phosphoric acid by fusion before the blowpipe, with boracic acid and iron wire; add, then, to the original solution, a solution of chloride of iron, supersaturate with ammonia, and filter. The phosphoric acid is hereby precipitated by the ammonia, in combination with the peroxide of iron; the alkaline earth is left in the filtered solution, and is to be detected, by treating it as described (37).

37. If no precipitate be produced in the original acidulated solution by sulphuretted hydrogen, or, after its saturation, with ammonia, by the addition of sulphhydrate of ammonium, the base must be one of 1—7. Supersaturate the solution with chlorohydric acid, boil and filter; then add a mixture of ammonia and carbonate of ammonia, and heat it. If no precipitate be formed, the absence of baryta, strontia, and lime is indicated, in which case, proceed as farther directed (38). On the other hand, the appearance of a precipitate indicates the presence of one of them. In order to distinguish them, add to another portion of the solution a saturated solution of gypsum. If no precipitate be apparent, the base is lime. For further proof, add to a fresh portion of the solution ammonia in excess, and then oxalate of ammonia, which produces a white pulverulent precipitate of oxalate of lime. If the original solution, by the addition of the gypsum, become turbid only after the lapse of some time, strontia may be suspected; for further proof, and to distinguish it from baryta, test with fluosilicic acid, which yields no precipitate with strontia or lime, but only with baryta. If a precipitate be formed immediately, by the addition of the solution of gypsum, the base is baryta.

38. If no precipitate be produced in the original solution, by the addition of a mixture of caustic and carbonated ammonia, add to a portion of the same, a solution of phosphate of soda. If the solution remain clear, even after gentle heating, the absence of magnesia is indicated; proceed, then, farther, as directed (39). If a precipitate appear, it is caused by phosphate of ammonia and magnesia, and proves the presence of the latter base.

39. If neither sulphuretted hydrogen, nor sulphhydrate of ammonia, nor a mixture of caustic and carbonate of ammonia, nor phosphate of soda produce a precipitate in the original solution, the base must be ammonia, soda, or potassa. A portion of the original solution, which has not been mixed with phosphate of soda, is evaporated to dryness, and ignited in a crucible, in order to expel all ammoniacal salts. If no residue be left after the ignition, it proves the absence of the fixed alkalies, soda and potassa, and the base must therefore be ammonia. For further proof, test the original substance under examination, by boiling a portion of it in a test-tube, with a strong solution of caustic potassa; ammoniacal vapors will be given off, and may be recognised by their odor or a piece of red litmus paper held in the open end of the tube.

40. If a fixed residue remain, after ignition,

the base is either soda or potassa. Add to the solution of the remaining solid residue or to a portion of the original solution, to which no ammonia has been added (for ammonia will produce a similar precipitate), a solution of chloride of platinum. If a heavy yellow precipitate be formed, either immediately or after some time, the base is potassa. If no precipitate be formed by chloride of potassium, the base is soda, to confirm which, add to a fresh portion of this solution, antimoniate of potassa, which will produce a precipitate of antimoniate of soda.

41. *Examination for the Acid.* It is of importance, in regard to the acid, to know whether the substance be soluble in water, or require the addition of an acid for its solution, and also to have discovered the base with which it occurs combined, as these two circumstances will greatly assist in forming an opinion in regard to the particular acid present. If the substance contain *arsenious* or *arsenic acid*, it will already have been discovered by the examination for the base.

42. If the substance be insoluble in water, but, on the addition of chlorohydric acid, dissolve with effervescence, or, if it be soluble in water, but an effervescence take place by the addition of this latter acid, it may arise from the escape of carbonic acid gas or sulphuretted hydrogen. If the gas be inodorous, it is *carbonic acid*, but if it have a disagreeable odor, and blacken a piece of lead-paper held over it, it is *sulphuretted hydrogen*, derived from a sulphuret or sulphhydrate.

43. *Sulphuric acid* is discovered by dissolving the substance in water and adding chlorohydric acid, or, if the latter produce a precipitate, nitric acid, and then a solution of chloride of barium, or, in the latter case, nitrate of baryta. If the substance be insoluble in water, it is dissolved in chlorohydric or nitric acid, and in the former case chloride of barium, in the latter, nitrate of baryta added. A white pulverulent precipitate of sulphate of baryta, insoluble in water and an excess of acid, indicates that the acid was the sulphuric.

44. *Chlorine* and *iodine* are discovered by dissolving a portion of the substance in water, with the addition of a small quantity of nitric acid, or if insoluble in water in the latter acid, and then adding a solution of nitrate of silver, which precipitates chlorine and iodine, as chloride or iodide of silver, both insoluble in water and an excess of nitric acid. If the precipitate dissolve in caustic ammonia, it is chloride of silver; if it prove insoluble in it, it is iodide of silver. *Bromine* causes a similar precipitate, but the bromide of silver dissolves with greater difficulty in ammonia than the chloride of silver. See under **BROMINE**.

45. A portion of the substance is thrown on a well-ignited piece of charcoal; if it cause a deflagration, it contains either *nitric* or *chloric acid*. To distinguish these, heat a portion of the substance moderately in a test-tube, with concentrated sulphuric acid and some clippings of sheet-copper. If red fumes are perceived to be formed in the tube, either immediately or by blowing into the tube, this indicates the presence of *nitric acid*. If the substance,

when heated by itself in its dry state in a test-tube, give off oxygen, recognisable by reigniting a glowing taper or match, being thereby converted into a chloride (tested, as indicated in 44), it contains chloric acid.

46. The presence of *boracic acid* is shown by the green color, which the substance imparts to flame, when mixed in its dry state with concentrated sulphuric acid and alcohol, and inflamed. The color is more distinct, when the mixture is stirred with a glass rod. The presence of *chromic acid* may, in most cases, be inferred from the yellow or red color of its combination, which color is changed into green by boiling with chlorohydric acid and alcohol, whereby it is converted into sesquioxide of chromium, which, then, may be detected as directed under the examination for the base (36).

47. If the substance contain *fluorine*, its presence is known by the corrosion which it causes on a piece of glass, when mixed in a platinum crucible, with concentrated sulphuric acid, and heated moderately. To be able to see the corrosion more distinctly, the glass should be covered with a thin layer of wax, and letters scratched through the wax. The crucible containing the mixture of the substance, with sulphuric acid, should be covered with the glass, turning the letters downward, to be acted on by the fumes, and a very gentle heat applied to the bottom of the crucible, while the glass on top is kept cool by a few drops of water. On removing the wax, the letters will be found corroded into the glass, if fluorine be present.

48. In regard to the phosphoric acid, it may be remarked, that only its combinations with the alkalis are soluble in water; the rest are all insoluble in water, but dissolve in chlorohydric and nitric acids, from which solution they are again precipitated by the neutralization of the acid. These circumstances may therefore afford an inference of its presence, when other acids which resemble it in this point, as arsenious, arsenic, boracic or fluohydric acids, have been ascertained to be absent. Of positive tests for phosphoric acid, none is so much to be relied on as the formation of a globule of phosphuret of iron, by fusion on charcoal before the blowpipe, with boracic acid, and subsequent introduction of a fine iron wire (see under **BLOWPIPE**); but for this purpose it is necessary first to ascertain that no metallic oxide be present, except the oxide of iron. The test also requires some practice before it succeeds and confidence in it is acquired. If the base with which it is combined, therefore, be an alkali, the solution is neutralized as near as possible, with ammonia and chloride of barium added. If this yields a precipitate which is soluble in an excess of the acid, and none of the above acids with which it could be confounded be present, the presence of phosphoric acid may be inferred; for further proof, subject a portion of the precipitate to the blowpipe-test; if it be combined with alumina or one of the alkaline earths, the surest test for its presence is directly by the blowpipe, as just mentioned (compare 36). If it be combined with a metallic oxide, this must

be separated by solution in chlorohydric acid, and precipitation by sulphuretted hydrogen, if it be precipitable by this reagent, otherwise, by digestion with sulphhydrate of ammonium. The filtered solution is then mixed with chlorohydric acid in excess and boiled, and chloride of barium added, which precipitates sulphate of baryta; if phosphoric acid be present, the phosphate of baryta is then precipitated, by neutralizing the acid with ammonia, and may be tested as before.

c.c. Those insoluble or sparingly soluble in Water, Chlorohydric or Nitric Acid, or Aqua Regia.

49. As among such substances, we shall here mention the following: the *sulphates of baryta, strontia, and lime, sulphate of lead, chloride of lead, and chloride of silver*: of these, sulphate of lime and chloride of lead are soluble in water, although sparingly, and may, therefore, be dissolved by treatment with larger quantities of this fluid. Sulphate of lead is soluble in strong chlorohydric acid, particularly by heat. The solution deposits, on cooling, crystals of chloride of lead. These substances may be distinguished from each other in the following manner:

50. A portion of the substance is treated with sulphhydrate of ammonium. If it become black, it may be inferred to be sulphate or chloride of lead, or chloride of silver. To distinguish these, digest it with sulphhydrate of ammonium, filter, wash the sulphuret of lead or silver, and treat it with dilute nitric acid. The solution is then filtered, and a portion of it tested by chlorohydric acid. If the formed precipitate be soluble by the addition of a large quantity of water, it indicates the presence of lead; for further proof, add sulphuric acid to another portion of the solution, and obtain a precipitate of sulphate of lead. If the precipitate produced by chlorohydric acid remain perfectly insoluble in water, the substance is chloride of silver; if the presence of lead be indicated, filter the solution from digestion with sulphhydrate of ammonium, and test it for chlorine (44) by supersaturating it with nitric acid, boiling and filtering, and then mixing it with nitrate of silver. If the substance be thus found to contain lead and chlorine, it was chloride of lead; if no chlorine be present, it was sulphate of lead; for further proof of the sulphuric acid, boil a portion of the substance with carbonate of soda, filter, supersaturate the solution with chlorohydric acid, and test for sulphuric acid by the addition of chloride of barium (43).

If the substance remain white by digestion with sulphhydrate of ammonium, it may be inferred to be either sulphate of baryta, strontia, or lime; to distinguish these, boil it with a concentrated solution of carbonate of soda or potassa, and filter while hot, without diluting it with water. The filtered solution may be tested for sulphuric acid by supersaturation with chlorohydric acid, and the addition of chloride of barium (43). The insoluble residue, from the treatment with carbonate of soda or potassa, is washed, treated with chlorohydric acid, and the solution tested for lime, strontia, or baryta, as directed (37).

Those containing any or all of the Ingredients enumerated in 31.

a a. Soluble in Water, Chlorohydric or Nitric Acid, or Aqua Regia.

51. *Detection of the bases, including arsenious and arsenic acids.* The solution of the substance is effected as before, either by water or chlorohydric or nitric acid, or by a mixture of them both. If the solution is effected by water, it is acidulated with a small quantity of chlorohydric acid, or, if this produce a precipitate, with nitric acid. If the solution were effected by an acid, it is merely diluted with water; should a turbidness be produced by the dilution, it may either be disregarded or so much acid added as is just sufficient to redissolve it.

52. A current of sulphuretted hydrogen is then passed through the solution, during occasional stirring, till it becomes perfectly saturated with this gas, which is ascertained, after previous stirring, by its coloring a strip of lead-paper brown or black; if no precipitate or only a slight milkiness of fine sulphur be formed, none of the bases 15—19 are present. If the milky precipitate of sulphur be abundant, it is well to collect it on a filter, wash, and test by roasting it in an open glass tube whether it contain any thing else (25). If it consist altogether of sulphur, it is due to the oxidation of sulphuretted hydrogen by some substance in the solution, such as peroxide of iron, which is thereby converted into protoxide. Proceed, then, as directed (56).

53. If a precipitate besides sulphur be produced by sulphuretted hydrogen, it may contain any of the bases 15—22, including 26. It is collected on a filter, and washed thoroughly with warm water. The washings should be set aside, and not mixed with the mother-liquid, in order to avoid too great dilution. The precipitate is pressed between blotting-paper, and removed from the filter into a small porcelain capsule or a digesting-vessel, or, if not very abundant, into a large test-tube, and treated with sulphhydrate of ammonium, containing an excess of sulphur. If any of the bases 20—22 or 26 be present, they will dissolve, and, if no precipitate remain, none of the bases 15—19 are present; then proceed as in (56); but, if any be left, it may contain any of these latter. Treat it as directed (55).

54. The filtered solution of sulphhydrate of ammonium is mixed with dilute chlorohydric acid till it has an acid reaction. If only a fine powdery or milky precipitate be hereby produced, it consists merely of sulphur, and none of the bases 15—19 or 26 are present. Beginners are often doubtful on this point. It is, therefore, better in all cases to collect the precipitate on a filter, press it between bibulous paper, and roast a portion of it in an open glass tube (25); this will at once satisfy the operator whether it contains any thing besides sulphur. If this be the case, test the precipitate for arsenic, as directed (27), and for tin, by roasting, and then reducing it with carbonate of soda before the blowpipe. If the precipitate be of an orange color, it indicates the presence of antimony; to test it further for this substance, and, at the same time, for the

presence of tin, dissolve a portion of it in strong chlorohydric acid, precipitate the metals by a strip of metallic zinc, remove the precipitate from the zinc and treat it with nitric acid. The oxides of antimony and tin remain then undissolved, and may be separated as directed (23). If gold be present, the precipitate from the sulphhydrate of ammonium has a dark color; its presence is easily recognised by the addition of sulphate of protoxide of iron to the original solution, when a yellow or black precipitate of metallic gold will be formed.

55. The residue left by the digestion with sulphhydrate of ammonium, and afterwards collected on a filter and washed, may contain any of the bases 15—19. It is tested for these as described (28).

56. The filtered solution from the precipitation by sulphuretted hydrogen, is neutralized or slightly supersaturated with ammonia, and mixed with sulphhydrate of ammonium. If no precipitate be formed, none of the bases 8—14 are present, nor are any of the phosphates of the alkaline earths, and the examination is then further pursued as directed (60).

57. If a precipitate be formed, it may contain any of the bases 8—14, besides phosphates of alumina and of the alkaline earths, or the fluorides of the metals of the latter, if the substance under examination should contain phosphoric acid or fluorine. The precipitate is filtered, washed with hot water, to which a few drops of sulphhydrate of ammonium are added, and then pressed between folds of bibulous paper. A portion of it is roasted in an open glass tube, or in a porcelain or platinum crucible, with free access of air, and employed for testing in the dry way, which will enable us to discover most of the bases it may contain; thus, by testing it before the blowpipe, with salt of phosphorus, a dark red color in the oxidizing flame, while the bead is hot, but mostly disappearing on cooling, and passing into a green in the reducing flame, and disappearing entirely by renewed heating, after the addition of metallic tin, is indicative of iron; a blue or colored bead in the oxidizing and reducing flame, indicates the presence of cobalt; a strong green color remaining in the reducing flame even after the addition of metallic tin, indicates chromium. The production of metallic spangles by reduction with carbonate of soda and subsequent trituration and washing with water in the agate mortar, shows the presence of nickel; and the formation of a white ring around the place where the substance is lying on charcoal, by the reduction with carbonate of soda, indicates the presence of zinc. Beginners are often apt to be doubtful of the latter reaction, and it is therefore better for them to rely on testing in the moist way, for its discovery. The presence of manganese is detected by the green color it yields, by fusion on a platinum foil with nitre and carbonate of soda.

58. The rest of the precipitate produced by sulphhydrate of ammonium, and not employed for testing in the dry way, is tested in the moist way by dissolving it in chlorohydric acid. If a dark brown or black precipitate remain, which does not dissolve or at least does so with

difficulty in chlorohydric acid, the presence of nickel or cobalt may be suspected. Some nitric acid is added, and the solution boiled, after which it is precipitated by ammonia in slight excess; if it produce no precipitate, none of the bases next to be mentioned are present; proceed, then, as directed (59). But if a precipitate be formed, it may contain peroxide of iron, alumina, oxide of chromium, and a small portion of oxide of manganese, the main portion of which will remain in the solution; it may also contain some of the above-named (57) insoluble phosphates or fluorides. The precipitate is filtered and washed with hot water; it is then removed from the filter in its moist state, and treated with a strong solution of caustic potassa, with the application of but a gentle heat. Caustic potassa will in this way dissolve alumina and oxide of chromium, but leave behind peroxide of iron, which is separated by filtration, washed, and for further confirmation, redissolved in chlorohydric acid, and tested with ferrocyanide of potassium (30). If the substance contained phosphoric acid or fluorine, phosphoric acid, the alkalino-earthly phosphates, and fluorides may be also contained in the precipitate left by treatment with caustic potassa. If this be suspected, treat it as described (36).

If the potassa solution from the peroxide of iron have a green tint, which indicates the presence of chromium, or, if this substance have already been detected by the blowpipe (57), the solution is diluted with water and kept in ebullition till the oxide of chromium has completely precipitated; for further proof, test the precipitate by the blowpipe for chromium. The filtered potassic solution is supersaturated with chlorohydric acid and ammonia added in slight excess; if alumina be present, it is thrown down by the ammonia as a perfectly white flocculent precipitate. A content of phosphoric acid, if such be suspected, may be discovered either by the blowpipe or by treating it as described in (36).

59. If the ammoniacal solution from the precipitation of peroxide of iron, oxide of chromium, and alumina, have a green color, the presence of nickel may be suspected; if it be of a faint pink color, it indicates the presence of cobalt; it is mixed with caustic potassa and heated. If the solution contain nickel, it will yield a precipitate of a light green color; if it contain manganese, the precipitate will at first be of a light color, but subsequently assume a dark brown color by oxidation in the air. The precipitate is filtered, washed, and tested by the blowpipe for these two substances, as indicated before. The filtered potassic solution is mixed with a small quantity of sulphhydrate of ammonium; if it contain zinc, it yields a white precipitate of sulphuret of zinc, which, for confirmation, is roasted and tested by reduction before the blowpipe; the latter test will also prove the existence of the zinc, if cobalt should be present, and cause a blackish precipitate by sulphhydrate of ammonium.

60. The solution from the precipitation by sulphhydrate of ammonium, is first tested to ascertain whether it still contain any fixed bases; this is best performed by evaporating

a small portion of it in a platinum or porcelain crucible, and ascertaining whether it leave any residue after ignition; in the latter case, it may still contain magnesia, lime, strontia, baryta, soda, and potassa. The solution is supersaturated with chlorohydric acid, boiled to expel the sulphuretted hydrogen, and filtered; it is then mixed with carbonate of ammonia, to which some caustic ammonia has been added. If, even after the application of gentle heat, no precipitate occurs, it contains neither lime, strontia, nor baryta; then test as in 63. Should, on the other hand, a precipitate take place, the above mixture of carbonated and caustic ammonia is added, till it causes no longer a precipitate, and the latter is separated by filtration and washed. The precipitate is dissolved in chlorohydric acid, and a portion of it mixed with a saturated solution of gypsum; if it, even after the lapse of some time, yield no precipitate, the absence of strontia and baryta is inferred, and the precipitate by caustic and carbonated ammonia consisted then only of carbonate of lime; for further proof of the presence of this, test a fresh portion of the solution with oxalate of ammonia, after the addition of ammonia in excess.

61. If a precipitate should appear upon the addition of gypsum, but only after some time, the presence of strontia may be inferred; but the absence of baryta should in this case be proved by the addition to another portion of the solution of fluosilicic acid, which produces a precipitate with baryta, but none with lime or strontia. Besides strontia, lime may also be present; ascertain this by precipitating the solution by sulphuric acid in excess, and after perfect subsidence, filtering the liquid, supersaturating it with ammonia, and adding oxalate of ammonia, which, when lime is present, produces a precipitate of oxalate of lime.

62. If a precipitate appear immediately on the addition of the gypsum to the chlorohydric solution, baryta is present; for further proof, add to another portion fluosilicic acid, which yields a precipitate with it. In this case strontia and lime may also be present; to ascertain which, evaporate a fresh portion of the hydrochloric solution to dryness, and treat it with absolute alcohol, filter and evaporate to dryness. If nothing have dissolved, strontia and lime are absent; but if the alcoholic solution yield a residue, it may contain these two bases; dissolve the residue, and test it by the addition of gypsum, &c., as directed (61).

63. The original solution, after precipitation by the mixture of caustic and carbonated ammonia, may still contain magnesia, soda, and potassa. A portion of it is mixed with a solution of phosphate of soda. If this produce no precipitate, either immediately or by gentle heating, magnesia is absent; while, on the other hand, the presence of this substance is indicated by the appearance of a rather flocculent precipitate of phosphate of ammonia and magnesia.

64. If no magnesia be present, the rest of the solution, to which no phosphate of soda has been added, is evaporated to dryness, and ignited in a platinum or porcelain crucible, in order to volatilize all ammoniacal salts; if a

fixed residue be left, it may contain soda and potassa. The residue is dissolved in water, filtered, if necessary, mixed with a solution of chloride of platinum, and evaporated nearly to dryness; if, on redissolving the mass in weak alcohol, no yellow heavy precipitate of chloroplatinate of potassum remain, it indicates the absence of potassa, and the remaining base is then soda; but if a precipitate be formed indicating the presence of potassa, the solution is filtered and evaporated to dryness, and ignited, whereby the excess of chloride of platinum is decomposed into metallic platinum. If, then, upon extraction of the mass by water and evaporating the solution, a residue remain, soda is also contained in the substance. The presence or absence of soda in the fixed residue left after the expulsion of the ammoniacal salt, may also be discovered by adding to a portion of its solution in water antimoniate of potassa, with which soda yields an insoluble precipitate of antimoniate of soda.

65. When magnesia is present and no sulphuric acid is contained in the solution, the rest of it, to which no phosphate of soda has been added, is in the same manner evaporated to dryness, and ignited for the expulsion of ammoniacal salts; but the mass is then kept for some time in ignition, with free access of the air. On redissolving the mass in water, the magnesia remains undissolved. The solution is filtered, and examined for potassa and soda as prescribed above in (64).

66. If, on the contrary, sulphuric acid be present in the solution, the separation of the magnesia is more difficult, since the sulphate of magnesia will bear ignition without being decomposed. The solution is evaporated and ignited, till perfect volatilization of ammoniacal salts, and, if necessary, some sulphuric acid added, and the excess of it again expelled; the mass is then dissolved in water and precipitated by acetate of baryta in a small excess. All the sulphates are thus converted into acetates, while the sulphuric acid combines with the baryta to form insoluble sulphate of baryta, which is separated by filtration. The filtered solution is evaporated to dryness and ignited to a moderate red heat, whereby the acetates are destroyed, and converted into carbonates; the carbonates of baryta and magnesia remain insoluble by subsequent edulcoration with water, and may be separated by filtration, while the carbonates of potassa and soda dissolve. The filtered solution is neutralized with chlorohydric acid and tested with chloride of platinum for soda and potassa, as pointed out in (64).

67. We have, in the course of this examination, entirely disregarded a possible content of ammonia. The presence of this ingredient in the substance under examination is ascertained by heating a portion of it in a test-tube with a solution of caustic potassa, whereby ammoniacal vapors are generated, and may be detected either by their odor or by the restoration of the blue color of a piece of red litmus-paper previously moistened and held in the mouth of the tube, taking care not to touch the side of the tube, or allow spiritings from the alkaline liquid to produce this effect.

68. *Examination for the Acids.* This investigation is usually conducted by testing separate portions of the substance, and therefore wholly carried on as pointed out (41—48). In regard to phosphoric acid, Berzelius prescribes as the best method of discovering it, when combined with metallic oxides or other substances that would interfere with the blowpipe-test, to dissolve the substance in a small portion of chlorohydric acid, or merely to mix it with it and then to saturate the acid solution at ordinary temperatures with freshly precipitated peroxide of iron, filter, and heat the filtered solution to ebullition, by which the peroxide of iron is precipitated in combination with the phosphoric acid, as a basic salt, in which the latter may be detected in the usual way by the blowpipe-test.

b b. Those insoluble or sparingly soluble in Water, Chlorohydric or Nitric Acid, or Aqua Regia.

69. We refer to (49), in regard to the substances of this class which are most commonly met with. From the rules laid down there and in the subsequent paragraph, it will also be easy to perform the examination when several of them occur together. A general method, by which the examination of oxidized substances insoluble in water or in acids may be facilitated, is first to attempt to decompose them by boiling with carbonate of potassa or soda, by which most of them are decomposed into insoluble carbonates of the bases which occurred in them, while the acids are taken up in solution combined with the alkali, and may be separated by filtration, and thus more easily examined for recognition. The separated bases are dissolved in a dilute acid, and examined by themselves. If the substance is not decomposed by boiling with a solution of the alkaline carbonates, it may almost always be decomposed by mixing it with three or four times its weight of dry carbonate of soda or potassa, and fusing the mass in a crucible. The fused mass is soaked or digested with water, and the solution separated from the insoluble residue by filtration. The latter, which contains all the bases, either as carbonates or oxides, or even reduced to metal, if the oxide of a very reducible metal, as silver or lead, be present, may then be examined by dissolving it in an acid. It is most safe not to perform the fusion in a platinum crucible if it contain any of the metals 15—21, but in a small clay or porcelain crucible; but the crucible is then always attacked more or less by the operation. In this case, however, these metals may also be separated by sulphuretted hydrogen or by digestion in a finely pulverized state with sulphhydrate of ammonium and subsequent filtration, by which the acids combined with the metallic oxides are obtained in the solution combined with ammonia. In case of fusion with carbonate of soda or potassa, the acids are obtained in the solution by water, combined with the alkali, and mixed with an excess of the alkaline carbonate.

d. Silicates.

70. The silicates constitute the greater part of the mineral kingdom. As previously stated,

they are easily recognised by fusion before the blowpipe, with salt of phosphorus, when the silica will remain insoluble and float about in the fused bead as a white spongy mass. The silicates contain comparatively few ingredients, these being, in a great measure, the same in most of them, merely differing in their relative proportion. The usual ingredients of silicates, besides silica, are alumina, lime, magnesia, oxides of iron, small quantities of oxides of manganese, soda, potassa, and chemically combined water. Some silicates contain, besides these, other more rare ingredients, which will afterwards be alluded to. The analysis of silicates of usual occurrence, containing only the above-named ingredients, is so simple that in most cases when a quantitative analysis is desired, it does not become necessary first to subject them to a qualitative examination, but the former may be undertaken at once.

71. The silicates form two great classes, of which one contains the silica in such a state that it may be separated by digestion with chlorohydric or any of the other stronger mineral acids; the other is not decomposed by them. When the silica is separated from the different silicates of the first class by one of the stronger mineral acids; it appears in two different states, either as a gelatinous or pulpy mass, or in a fine, light, and pulverulent state. Silicates of the latter class never contain chemically combined water, and are much more difficult of analysis than the former, requiring an entirely different method. To ascertain whether a silicate belongs to the one or the other of these classes, a small portion of it is finely pulverized and heated with strong chlorohydric acid in a large test-tube, when it may be easily observed whether any action takes place on it. Should it become gelatinous, it proves at once that it is decomposed. If, however, the silica separate as a light powder, the difference of its pulverulent appearance from that of the silicate will also be very observable; the acid will also be found to have dissolved the bases, which may be ascertained by evaporating a small portion of it to dryness. For greater certainty, however, the remaining silica is filtered, washed, removed into a clean test-tube, and then boiled with a concentrated solution of carbonate of soda, and filtered or decanted hot. If, then, on cooling, and still more by supersaturation with chlorohydric acid, silica be separated in a gelatinous state, it proves conclusively that the silicate has been at least partly decomposed. If, on the contrary, no action by the acid be apparent after digestion for some time, and nothing taken up into solution, and if, by subsequent treatment of the residue with carbonate of soda, no silica be dissolved, the silicate under examination belongs to that class which is not decomposed by digestion with acids.

72. *Silicates decomposable by Acids.* A portion of the finely pulverized silicate is decomposed by digestion with chlorohydric acid; and after decomposition a few drops of nitric acid added while yet hot. The silica is filtered off and the solution precipitated with ammonia in slight excess. The precipitate caused thereby may consist of alumina and peroxide of iron; if it be

white, it consists principally of alumina; if its color be brownish, it contains peroxide of iron, with which more or less alumina may be mixed. The precipitate is separated by filtration, washed thoroughly, scraped from the filter, and boiled with a solution of caustic potassa, which dissolves the alumina, if the latter be present, while the oxide of iron is left insoluble, of a dark brown color. The potassic solution is separated by filtration, and supersaturated with chlorohydric acid, and then ammonia added till it assumes an alkaline reaction. If alumina be present, it is then made apparent as a white flocculent precipitate.

73. The original solution which has been filtered from the precipitate caused by ammonia is mixed with a solution of oxalate of ammonia. This precipitates lime, if it be present, as fine, white, pulverulent oxalate of lime. If no precipitate should appear, it indicates the absence of lime; but if the latter be present only in a small quantity, the oxalate of lime will not appear until after some time. The solution ought, therefore, to be gently heated to facilitate its separation. When lime is found to be present, it should be completely precipitated by the addition of a sufficient quantity of oxalate of ammonia, and after its separation by filtration, the clear solution ought always to be tested to ascertain that it has an alkaline reaction, and that a new addition of a few drops of oxalate of ammonia causes no more precipitate.

74. If oxide of manganese be present, which is best ascertained in a separate experiment, by fusing a portion of the powdered substance with nitre and carbonate of soda, a small portion of it is precipitated by the ammonia and is mixed with the peroxide of iron, but the main portion remains in the solution, and may now be precipitated after the separation of the lime by addition of sulphhydrate of ammonium to the solution. The sulphuret of manganese thus precipitated is separated by filtration. Manganese is, however, but rarely present in any quantity. After the separation of the manganese, the solution is supersaturated with chlorohydric acid and filtered. If no manganese has been found, the precipitation by sulphhydrate of ammonium is of course dispensed with.

75. The subsequent treatment for discovering the presence of magnesia, soda, and potassa is performed exactly as prescribed (63—66), to which the operator is referred.

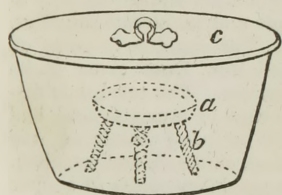
76. *Silicates which are not decomposable by Chlorohydric* or any of the common mineral acids, are either rendered so by fusion with carbonate of soda, or they are decomposed by fluohydric acid. The latter is especially resorted to when they are to be tested for the presence of soda or potassa.

77. The fusion with carbonate of potassa is executed by mixing the finely pulverized silicate with about three or three and a half times its weight of the alkali, and exposing the mixture for some time in a covered platinum crucible to a bright red heat, either in the flame of the argand spirit-lamp or the argand gas-burner, assisted by the jet of the table-blowpipe; or by the heat of a furnace, placing the platinum

crucible inside a covered hessian crucible, in order to protect it from contact with the coals. The heat must be sufficient to fuse the mass completely, and keep it in this state for some time; otherwise the decomposition will not be complete. The fused mass is first soaked for some time in a sufficient quantity of cold water, after which it is removed from the crucible into a small capsule, mixed with chlorohydric acid till it becomes strongly acid, and then evaporated almost to dryness, by which the silica becomes insoluble. The mass is then treated with water, acidulated by chlorohydric acid, filtered, and further tested as described (72—75), excepting that having introduced a large amount of carbonate of soda, the testing for soda and potassa is omitted, as the exact amount of the former could not be ascertained, and that of small quantities of the latter with uncertainty.

78. For the purpose of testing undecomposable silicates for soda and potassa, they may, in some instances, be decomposed by ignition with 4 or 5 times their weight of carbonate of baryta at a very high temperature. The mass is then treated with water and chlorohydric acid, and after the separation of the silica, as described above, all the bases except the magnesia and the alkalis may be precipitated by a mixture of caustic and carbonated ammonia, and the remaining liquid tested for magnesia and the alkali, as prescribed (63—65). But a far preferable method is to decompose such silicates by fluohydric acid. This acid decomposes all silicates, even at ordinary temperatures, on which account the decomposition must be performed in a platinum vessel. As the preparation of pure fluohydric acid also requires a platinum retort, Brunner has proposed the following apparatus, which may be procured at a slight expense, and answers every purpose. It consists of a leaden vessel, fig. 25, with its cover, c, of the same metal;

Fig. 25.



vered with pure water. The bottom of the leaden vessel is covered with coarsely pulverized fluorspar to the depth of about $\frac{1}{4}$ inch, and then made into a paste with concentrated sulphuric acid. The leaden tripod is next placed about the centre of the mass, the platinum dish with the pulverized silicate mounted on it, the apparatus covered with the leaden cover and heated to a moderate warmth in a water-bath. The vapor of fluohydric acid being given off from the mixture at the bottom of the vessel, fills it entirely, and, condensing in the platinum dish, decomposes the silicate completely. If the latter be mixed with but little water, it is converted into a gelatinous, transparent mass; but with a larger quantity of water often dissolves almost entirely. The apparatus should now and then be opened quickly and examined,

to observe the progress of the decomposition, and the silicate stirred with the small spatula. If it should become dry, it must be moistened again with water. When the whole mass has been decomposed, the platinum dish is removed, mixed with pure concentrated sulphuric acid, and heated till it becomes dry and the excess of the sulphuric acid has been expelled. By this process the silica combines with the fluohydric acid, forming fluoride of silicon, which is expelled by the subsequent addition of sulphuric acid and heat. The remaining mass is then moistened with chlorohydric acid and transferred to a digesting-vessel, and digested with a sufficient quantity of water, acidulated with a little muriatic acid till it becomes completely dissolved. If the silicate contain a large proportion of lime, the sulphate of lime will require a larger portion of water for its solution. All the bases are thus obtained in solution, combined with sulphuric acid. The alumina and peroxide of iron are then precipitated as before by ammonia, and separated by caustic potassa. The lime is next precipitated by oxalate of ammonia, and the manganese, if present, by sulphhydrate of ammonium. The remaining solution is then tested for magnesia, soda, and potassa (66).

79. As ingredients of rare occurrence in silicates, may be mentioned *baryta* and *strontia*, which are distinguished from lime, as directed (38); *glucina*, forming an important constituent of emerald or beryl, euclase, and a few other minerals, and generally occurring in connection with alumina, from which it is separated after their precipitation by ammonia, by digestion with carbonate of ammonia, which dissolves glucina, but leaves alumina undissolved. *Ytria* has been found in pyrope and several other minerals; it generally occurs associated with oxides of cerium and lanthanum; *thoria* is of the rarest occurrence; *zirconia* forms one of the ingredients of hyacinth and zircon. All these last-mentioned earths are distinguished from alumina and glucina by their insolubility in caustic potassa, and by the insolubility of their double sulphates of potassa, when precipitated from their solution by a hot saturated solution of sulphate of potassa. *Titanic acid* is best discovered by its reaction with salt of phosphorus before the blowpipe (see under *TITANIUM*). Other substances, such as *metallic oxides*, *phosphoric acids*, *fluorine*, &c., are either discovered by the blowpipe or in the moist way, after decomposition of the silicate, as pointed out (52, &c.).

2. Quantitative Analysis of Solid Substances.

80. Instead of enumerating how every substance is separated for quantitative estimation from all others with which it might occur combined, which would swell the present essay into a large volume, we propose to give, in the way of illustration, a number of examples of the quantitative analysis of certain substances belonging to the different classes treated of under qualitative analysis, and selected with a view to their general interest. We, therefore, presume their constituents to have been previously ascertained by a qualita-

tive examination. In regard to the different manipulations and operations mentioned in the following examples of quantitative analysis, we refer to (3—20), where they have been described in detail. From the weight of the different combinations in which the ingredients are obtained during the analysis, their weight in the substance under analysis is computed by aid of the tables given at the end of this article, where the manner of using them will likewise be explained.

81. *Quantitative Analysis of an Alloy*, consisting of copper and zinc, with smaller quantities of tin, lead, and iron, constituting *bronze*. The metal is reduced to filings by a clean file: of these a weighed quantity, say one and a half to two grammes, is treated in a digesting-glass with nitric acid by the aid of heat. All the metals are then oxidized by the nitric acid and dissolved, with the exception of the oxide of tin, which is left behind, and separates completely on subsequent repose. The oxide of tin is separated by filtration and washed thoroughly on the filter with hot water, by the aid of the syringe-bottle (11). It is then removed on the filter from the funnel, dried and ignited in a porcelain crucible, with the access of air, and weighed, deducting the weight of the ashes of the filter. The solution and the washings from the oxide of tin are mixed with sulphuric acid in excess, and left some time at rest for the complete separation of the lead as sulphate of lead, which is in the same manner separated by filtration, dried, and calcined cautiously, with free access of the air, in a porcelain, or with care in a platinum crucible, and its weight ascertained. The washings are again mixed with the main liquid and a current of sulphuretted hydrogen passed through it, till, after thorough stirring, it smells of sulphuretted hydrogen and blackens a slip of lead-paper dipped into it. Sulphuretted hydrogen precipitates the copper completely as black sulphuret of copper, which is filtered quickly, employing a large filter for this purpose, in order to prevent an oxidation first of the free sulphuretted hydrogen by the free nitric acid, and afterwards of some of the sulphuret of copper, which would thereby redissolve. The sulphuret of copper is washed quickly with hot water, dried, and roasted in a porcelain crucible, by which the filter is incinerated, and the sulphuret of copper converted by the oxygen of the air into basic sulphate of copper, which, by stronger ignition, loses its sulphuric acid, and is converted into pure oxide of copper, the weight of which is ascertained. Another method is to wash the sulphuret of copper from the wet filter, while yet in the funnel, by the syringe-bottle into a small porcelain capsule. Open and spread the filter on a glass pane and remove any adhering particle by a few drops of nitric acid and subsequent washing with the jet of the syringe-bottle, then oxidize the sulphuret of copper in the capsule, by boiling with nitro-muriatic acid till the separated sulphur has become perfectly yellow, filter the solution and precipitate the oxide of copper during ebullition in a porcelain capsule, by a solution of caustic potassa in moderate excess.

The oxide of copper is then filtered, washed carefully, ignited, and weighed. If some oxide of copper should adhere to the capsule, it may be removed by a feather (10) or by redissolving it in a few drops of nitric acid, and precipitating it again by boiling, after the addition of a few drops of caustic potassa, and throwing it on the filter with the rest.

82. The original solution from the sulphuret of copper, with the washings, are concentrated in a porcelain capsule and then mixed during ebullition with carbonate of soda till it assumes a strong alkaline reaction, by which the zinc is precipitated as carbonate; but the filtered liquid should be tested by sulphhydrate of ammonium to ascertain that the precipitation has been completed. The carbonate of zinc is filtered, washed, dried, and ignited, by which it loses its carbonic acid, and is converted into oxide of zinc, the weight of which is ascertained. If iron be found present in such quantity as to make it desirable to ascertain its quantity, the oxide of zinc is redissolved, after being weighed, by digestion with chlorohydric acid, and the peroxide of iron precipitated by strong caustic ammonia in great excess. The peroxide of iron is filtered, washed, ignited, and weighed, and its weight deducted from that of the oxide of zinc. From the obtained weights of the oxide of tin, sulphate of lead, oxides of copper, zinc, and iron, the respective weight of their metals in the alloy is calculated. (See Tables at close of this article.)

83. *Quantitative Analysis of Sulphuret of Copper with Sulphuret of Iron (Copper Pyrites)*. The mineral is crushed and pulverized finely in an agate mortar. A weighed portion of it, say one to two grammes, is introduced into a digesting-glass and fuming nitric acid added as long as any action is observed. It is then digested with the acid at a moderate temperature till the separated sulphur has become perfectly yellow. The solution is then diluted with water and filtered; the residue is washed, dried, calcined cautiously in a porcelain crucible to volatilize the sulphur and incinerate the filter, and then weighed. The residue consists of oxide of copper and iron, from some undecomposed copper pyrites. The residue is dissolved in a small portion of muriatic acid, and if any gangue should be found remaining, it is separated by filtration, calcined, and weighed. The solution of the residuary oxides of copper and iron is added to the main solution.

84. This latter is then heated gently and mixed with strong ammonia in considerable excess, which precipitates the peroxide of iron, but retains in solution the oxide of copper. The peroxide of iron is separated by filtration, washed with hot water, dried, ignited, and weighed. The filtered solution is then transferred to a capsule, heated to ebullition, and a solution of caustic potassa added successively, till the solution, viewed against a clean white portion of the capsule below the level of the liquid, has lost all appearance of its blue color. The oxide of copper is then separated by filtration, washed, ignited, and weighed.

85. In order to ascertain the quantity of sulphur, a fresh portion of the powdered substance is intimately mixed with three times

its weight of a mixture of equal parts of finely pulverized nitre and carbonate of soda, and heated to fusion in a porcelain crucible. With sufficient caution, the fusion may also be performed in a platinum crucible, but it will then be found advantageous, previously to the introduction of the mixture into the crucible, to have covered its interior surface, by fusion, with a thin layer of carbonate of soda, in order to prevent the oxide of copper from adhering. By fusion with the above mixture the sulphur is oxidized by the nitric acid of the nitre, and converted into sulphuric acid, while the metals are converted into their respective oxides. The latter remain undissolved by subsequent edulcoration of the mass with water, and are separated by filtration and washed. The filtered solution, with the washings, containing all the sulphur as sulphuric acid, is supersaturated with chlorohydric acid, heated gently, and precipitated by a solution of chloride of barium as long as it causes any precipitate of sulphate of baryta. The latter is then separated by filtration, washed, dried, ignited, and weighed. From the obtained weights of the oxides of copper and iron, and the sulphate of baryta, the weights of the metals and the sulphur are calculated.

86. *Quantitative Analysis of Limestones.* Carbonate of lime, associated with more or less carbonate of magnesia, forms the principal ingredient of limestones. In some varieties the latter substance appears only as a trace, while in others, it amounts to nearly 50 per cent. of the mass. When the proportion of the carbonate of magnesia is very considerable, the rock is termed magnesian limestone, or dolomite, the latter name being mostly applied to the crystalline varieties. Variable quantities of other substances, as silica, alumina, and the oxides of iron, and manganese, are generally associated to some extent with the above principal constituents.

The limestone is first finely powdered, when a given weight, about 2 grammes, is digested in chlorohydric acid in the ordinary way and filtered. The silica and a large part of the other adventitious substances are thus left upon the filter. They are washed, calcined, and weighed, a correction being made for the weight of the ashes of the filter. These steps give the amount of the *insoluble matter*.

The filtered solution, containing, besides the lime and magnesia, portions of alumina and oxides of iron, is precipitated by ammonia in excess. When the precipitate has subsided, it is filtered quickly, the funnel being covered with a glass plate to exclude the atmosphere, and washed. The filter, with its contents, is then removed, pressed between bibulous paper, dried and calcined. The alumina and oxide of iron are thus obtained together. When their quantity is such as to require them to be separately estimated, it can be done in the ordinary way.

In determining the lime and magnesia, a fresh equal portion of the powdered mineral is employed, which is decomposed by a sufficient quantity of dilute sulphuric acid, with the aid of heat. More water is then added, after which alcohol of common strength (0.835 spec.

grav.) is introduced in the proportion of a little less than a volume equal to the mixture in the glass, and mixed well with it. The alcoholic solution precipitates entirely the *sulphate of lime* along with the insoluble matters. When the precipitate is settled, it is filtered under cover of a glass plate, and repeatedly washed with dilute alcohol, made by mixing 5 volumes of alcohol (spec. grav. 0.835) with 6 to $6\frac{1}{2}$ vols. of water, until a barytic solution indicates no trace of sulphuric acid. The whole is now calcined, and the weight of the insoluble matters, as already ascertained, being deducted, we obtain the amount of *sulphate of lime*, from which we compute that of the *carbonate*.

The filtered solution now contains the sulphate of magnesia and an inconsiderable portion of the sulphates of alumina and iron, besides an excess of sulphuric acid. It is to be evaporated to dryness in a porcelain capsule, transferred to a platinum or porcelain crucible, strongly ignited and weighed. Subtracting from the weight of the whole, that of the alumina and oxides of iron, previously ascertained, we find the amount of the sulphate of magnesia, which is to be estimated as carbonate.

The separation of the lime in the form of sulphate from magnesia, by an alcoholic solution, is so complete as to make it unnecessary to estimate directly the magnesia, except when we desire to check one result by the other.

The limestones generally contain a small portion of chemically combined water, varying from 0.5 to 0.8 per cent., which, for practical purposes, may be disregarded. If it be desired to ascertain its exact amount, this may be done either by heating a portion of it to a temperature below that at which the carbonates are decomposed, and ascertain the loss, or by the method described (90), collecting the water in a tube containing chloride of calcium.

87. The following analysis of a white crystalline dolomite from the neighborhood of Montville, New Jersey, will afford an example:

Specific gravity of the limestone 2.85.

A portion, 1.469 grammes, was raised to a dull red heat, and the water, which was received in a tube containing chloride of calcium, was found to weigh .007 grammes or .48 per cent. This small amount of water is not expelled at the temperature of boiling water.

Two other portions of the powdered mineral, treated after the method described, gave these results:

	Per cent.
Insoluble matter.....	.04
Alumina and oxide of iron.....	.15
Sulphate of lime and insol. matter..	76.09
Sulphate of magnesia, alumina, and oxide of iron.....	60.59

By subtracting the insoluble matter .04 from the joint weight of the insoluble matter and sulphate of lime 76.09, we get 76.05, and subtracting the alumina and oxide of iron from the joint weight of these and the sulphate of magnesia, we have for the sulphate of magnesia 60.44.

A reference to the tables, the use of which will be explained, shows that 76.05 per cent. of sulphate of lime is equivalent to 31.54 per

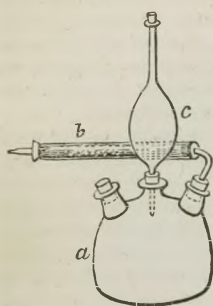
cent. of lime, or to 56.11 per cent. of carbonate of lime.

It also appears that 60.44 per cent. of sulphate of magnesia is equivalent to 42.54 of carbonate of magnesia. The result will therefore stand thus:

Carbonate of lime.....	56.11
Carbonate of magnesia.....	42.54
Alumina and oxide of iron.....	0.15
Insoluble matter.....	0.04
Water.....	0.48
	99.32

88. *Estimation of Carbonic Acid.* To ascertain the quantity of carbonic acid in limestones, or in any other carbonate, we employ an apparatus of the annexed figure. (Fig. 26.) It

Fig. 26.



consists of a small three-necked bottle, *a*, into which is introduced a quantity of the substance, the weight of which has either been previously ascertained or may be determined still better by weighing subsequent to its introduction into the bottle, the latter having been previously counterpoised. *b* is a glass tube containing fragments of chloride of calcium; having a small orifice at the one end for the escape of the carbonic acid gas, and fitted with the other into one of the necks of the bottle, *a*. *c* is a pipette, the bulb of which is filled with the acid, either chlorohydric or sulphuric, of the proper strength, employed for the decomposition of the carbonate. The third neck of the bottle is used for the introduction of the substance. The carbonate being introduced into the bottle and its weight known, the pipette, *c*, is filled with the acid, its upper orifice closed by a cork, and its lower end fitted into the middle neck of the bottle by means of a perforated cork, having previously wiped off all acid on the outside. The third neck being closed by a cork and the apparatus counterpoised, the acid is let down on the carbonate by opening the cork at the upper extremity of the pipette, till it has become nearly empty, when the cork is again restored to its place. The acid expels the carbonic acid, which, by passing through the chloride of calcium tube, deposits all moisture. To complete the decomposition of the carbonate, especially if it be carbonate of iron, the apparatus may be heated gently. After perfect decomposition, the carbonic acid remaining in the apparatus is removed by applying the mouth to the chloride of calcium tube and drawing atmospheric air through it, having loosened the cork in the pipette. The whole apparatus is then returned to the balance and its loss in weight ascertained, which yields the amount of carbonic acid in the substance.

89. *Analysis of Green Sand.* The constituents of green sand are silica, oxides of iron, alumina, lime (not always present), magnesia,

potassa, and water. It belongs to the class of hydrated silicates, and is therefore decomposed by acids. Some varieties are, however, of very difficult decomposition, and require for this purpose a protracted digestion for several days with very strong chlorohydric acid.

a. A weighed quantity (say one to one and a half grammes) is decomposed by digestion with strong chlorohydric acid. Previous pulverization accelerates the decomposition; but by longer time it may be effected in the granular state. When perfect decomposition has taken place, which is known from the entire disappearance of the greenish color, some nitric acid is added to convert the protoxide of iron into peroxides. The residue is then filtered, washed, ignited, and weighed, and yields the amount of silica or insoluble matter.

b. The filtered solution is heated and precipitated by caustic ammonia till it, after stirring, retains an alkaline reaction. The precipitate, which consists of peroxide of iron and alumina, is collected on a filter and washed thoroughly with hot water. It is then washed from the filter by the syringe-bottle into a porcelain capsule, and heated with a solution of caustic potassa, which dissolves the alumina, but leaves the peroxide of iron; the latter is separated from the potassic solution by filtration, washed first with hot water alone, which washings are added to the filtered solution, and subsequently with water, to which is added a few drops of a solution of chloride of ammonium to dissolve the potassa, which otherwise cannot be thoroughly removed from the peroxide of iron. After final washing with pure water, the latter is dried, incinerated, and weighed. The iron is generally considered to exist in green sand as protoxide, and therefore calculated as such from the peroxide. The potassic solution filtered from the peroxide of iron is supersaturated with chlorohydric acid and precipitated by ammonia or carbonate of ammonia till it assumes an alkaline reaction. The alumina, which hereby precipitates, is collected on a filter, washed carefully with hot water, dried, incinerated, and weighed.

c. The solution filtered from the alumina and peroxide of iron (*b*) after their precipitation by ammonia, is mixed with a few drops of oxalate of ammonia. If it cause any precipitate, more is added to complete the precipitation of all the lime. The oxalate of lime is left to subside, filtered, washed, dried, and, by incineration at a low red heat, converted into carbonate of lime, from the weight of which, that of the lime is computed.

d. The solution filtered from the oxalate of lime, contains the magnesia and potassa combined with chlorohydric acid. It is evaporated to dryness in a porcelain capsule, transferred into a counterpoised porcelain or platinum crucible, heated for the expulsion of all ammoniacal salts, and then kept for some time at a low red heat, placing once or oftener a piece of carbonate of ammonia on the ignited mass, and covering it to keep it in contact with the ammoniacal vapors. The mass, which consists of chloride of potassium and magnesia, is then allowed to cool and weighed. On dissolving it in water, the magnesia remains

insoluble, and is separated by filtration, ignited, and weighed. Deducting its weight from the joint weight of it and the chloride of potassium, that of the latter is obtained, from which the amount of *potassa* is computed. A more accurate separation of the magnesia from the chloride of potassium may be effected by dissolving the mass, after the volatilization of the ammoniacal salts, in a small portion of water, adding some peroxide of mercury, again evaporating it to dryness, igniting and weighing it. The mass is then treated, as before, with water, which leaves the magnesia undissolved.

e. To ascertain the quantity of water, it is, for most practical purposes, accurate enough to ignite a weighed portion of the green sand in a covered crucible and ascertain the loss. By the ignition, however, a portion of the protoxide of iron is converted into peroxide, which increases the weight of the remaining mass. If it, therefore, be desired to ascertain the weight of the water directly, it may be performed as in the following (90).

90. *Estimation of Water.* To determine the quantity of water in hydrated substances, introduce a weighed quantity into a small test-tube, the lower end of which may have been somewhat expanded into a bulb before the blowpipe; adapt a perforated cork to the other end, and connect it by the perforation with Liebig's chloride of calcium tube (*b*, fig. 2, Pl I.), as described under *Organic Analysis*. The whole apparatus is kept in a horizontal position or inclined slightly forward, while the end of the test-tube, containing the green sand, is heated by a single-wicked spirit-lamp. The water is thus expelled and condensed or absorbed in the chloride of calcium tube. The increase in weight of the latter indicates, therefore, the amount of water. This apparatus answers admirably for the direct determination of water in many other cases, especially where combined with other volatile matters, such as carbonic acid. In the latter case, the carbonic acid remaining in the apparatus must be removed, previous to its weighing, by a slight suction of air with the mouth at the end that was not connected with the test-tube.

91. *Analysis of Felspar.* The different varieties of felspar belong to that class of silicates which are not decomposed by acids. We suppose it, in the present case, to contain silica, peroxide of iron, alumina, lime, magnesia, soda, and potassa. The felspar is crushed in the steel mortar and pulverized finely in an agate mortar.

a. A certain weight (1 to 2 grammes) is then mixed thoroughly with three and a half times its own weight of anhydrous carbonate of soda, and the mixture fused in a platinum crucible for 15 to 20 minutes. If the fusion be performed by the spirit or gas argand-lamp, it is necessary to use the jet of the table-blowpipe. If, after complete fusion, the crucible be removed by a forceps, and, by appropriate movements, the melted mass be made to run around and cool on the inner sides of the crucible, it will greatly facilitate the subsequent solution in water. This is effected by soaking the crucible in water for some time, when the fused

mass may be completely loosened from it and transferred into a porcelain capsule, and all adhering particles removed by dilute chlorohydric acid, which is added to the mixture in the capsule. The fused mass being entirely softened, and if any lumps should exist, these being crushed in the capsule by the careful use of a pestle, the mixture is supersaturated with chlorohydric acid, and the acid solution evaporated nearly to dryness, avoiding any loss by spirting (16). The mass is then moistened with chlorohydric acid and redissolved in water. The *silica* remains hereby insoluble, and is separated by filtration, washed, dried, ignited, and weighed.

b. The filtered solution is heated and mixed with ammonia in excess, which precipitates *alumina* and *peroxide* of iron. They are separated from each other as described under the analysis of green sand (89. *b*). The filtered solution is precipitated by oxalate of ammonia, and the oxalate of lime separated and converted into carbonate of lime (89. *c*). The amount of *lime* is computed from the obtained weight of the carbonate of lime.

c. The solution filtered from the oxalate of lime is heated to ebullition, carbonate of soda added in excess to expel the ammonia, and the whole evaporated to dryness. On redissolving the mass in boiling water, the *magnesia* remains as carbonate, which is filtered, ignited, whereby it loses its carbonic acid, and weighed. It may, however, be remarked that, as many felspars contain only small traces of magnesia, the residue, if small, should be redissolved and tested for this substance. On account of the introduction of so large a quantity of carbonate of soda for fusing the mineral, the amount of the latter base in the felspar cannot be estimated in this way; but if the soda employed be pure, the remaining solution may be tested for potassa by the addition of chloride of platinum, and even its quantity tolerably well ascertained by evaporating the mass to dryness and treating it with alcohol in the usual manner for the estimation of this base (91. *g*).

d. In order to estimate the quantity of soda and potassa, a separate analysis must be made of another portion by fluohydric acid. For this purpose, a weighed quantity (1 to 2 grammes, depending on the size of the apparatus for its decomposition) is decomposed by fluohydric acid as described in (78). The decomposition is complete when the powder has disappeared entirely, and the whole is either dissolved or converted into a paste-like mass. It is then treated on the platinum dish with concentrated sulphuric acid, and heated till it becomes perfectly dry and the excess of sulphuric acid is expelled. It is then moistened with chlorohydric acid, transferred to a digesting-vessel, and digested with water to which has been added some chlorohydric acid, by which it dissolves completely, but slowly, particularly if the heat should have been raised so high as to cause part of the alumina to lose its sulphuric acid.

e. The solution is then precipitated by ammonia, and the alumina and peroxide of iron separated as before (89. *b*). The lime is then

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precipitated from the filtered solution by the addition of oxalate of ammonia. The quantities of these three substances ought of course, if estimated, to correspond to that obtained in the previous experiment by fusion with carbonate of potassa.

f. The filtered solution from the oxalate of lime is evaporated to dryness in a porcelain capsule, transferred to a platinum crucible, and ignited to expel ammoniacal salts. The remaining mass, which consists of the sulphates of magnesia, soda, and potassa, is then dissolved in water and precipitated by a solution of acetate of baryta in excess. The sulphates are hereby converted into acetates. The solution is filtered from the insoluble sulphate of baryta, and with the washings evaporated to dryness in a small porcelain capsule, and heated either in the latter or after being transferred into a crucible to complete the charring of the acetates, by which they are converted into carbonates. Of the latter, the carbonates of magnesia and baryta are insoluble, and remain, therefore, by treatment of the mass with water. They are separated by filtration, washed, and, if it be desired to estimate the magnesia, treated with dilute sulphuric acid, which dissolves the magnesia, but leaves behind insoluble sulphate of baryta, which is separated by filtration. The filtered solution containing the sulphate of magnesia, is evaporated to dryness, ignited, and weighed, and from the amount of sulphate of magnesia that of the magnesia computed.

g. The solution filtered from the carbonates of magnesia and baryta is supersaturated with chlorohydric acid, evaporated to dryness, and heated in a crucible to a commencing red heat, and its weight ascertained; it yields the joint weight of the chlorides of sodium and potassium. They are dissolved in water, mixed with chloride of platinum, evaporated to dryness in a water-bath, and then treated with alcohol of 0.84. The chloroplatinate of potassium thus left is collected on a counterpoised filter, washed with alcohol, dried, and weighed on the filter. From its weight the amount of potassa is computed, and also its equivalent of chloride of potassium. Subtracting the latter from the joint weight of the chlorides of sodium and potassium, previously obtained, we obtain the weight of the chloride of sodium, from which the amount of soda is computed.

C. ANALYSIS OF GASES.

92. Gaseous substances are generally collected over water, both on account of its greater convenience and from the expense attendant on the use of mercury for this purpose. The employment of the latter becomes, however, necessary when the gases are absorbed largely by water, or where great accuracy is desired in their quantitative estimation. The gas may either be collected in larger bell-glasses, from which smaller portions are subsequently drawn for the purpose of their examination, but in most cases it will be found preferable to collect them at once in glass tubes, in which they are afterwards examined. These glass tubes are sealed at the one end, and should not be made wider than $\frac{1}{2}$ inch or a little more, from the difficulty of closing the

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orifice of larger tubes with the finger. They are used of different lengths, from that of a common test-tube to 15 inches or even longer. By the collection of gases over water an excellent pneumatic trough for these tubes may be made out of a common water-basin, or even of a porcelain capsule, by placing at the bottom of it a loose ring made of a slip of sheet-lead, having the upper edge notched, on which the mouth of the tubes are placed while their bodies rest against the side of the basin, or, if longer, are kept in the upright position by a clamp or holder.

Among the gases ordinarily occurring, we select the following:

- | | |
|--------------------------------|----------------------------|
| 1. Oxygen, | 11. Chlorohydric acid, |
| 2. Hydrogen, | 12. Cyanohydric acid, |
| 3. Light carburetted hydrogen, | 13. Ammonia, |
| 4. Olefiant gas, | 14. Carbonic acid, |
| 5. Phosphuretted hydrogen, | 15. Sulphurous acid, |
| 6. Arseniuretted hydrogen, | 16. Chlorine, |
| 7. Carbonic oxide, | 17. Cyanogen, |
| 8. Nitric oxide, | 18. Sulphuretted hydrogen. |
| 9. Nitrous oxide, | |
| 10. Nitrogen, | |

93. The gas to be examined is first shaken with a concentrated solution of caustic potassa, by which all the gases 11—18 are absorbed, while 1—10 are left behind.

94. *Examination of the Gas left by caustic Potassa.* A portion of the gas left unabsorbed by caustic potassa is first tried in regard to its combustibility. If it burn when inflamed in contact with the atmosphere, it must principally consist of one or more of the combustible gases 2—7.

If this be not the case, but the gas, on the contrary, support the combustion of a glowing taper, it contains oxygen or nitrous oxide.

If it explode by ignition, it contains a mixture of combustible gases with oxygen.

If it be neither inflammable nor support the combustion of a glowing taper, it consists principally of nitrogen or nitric oxide.

95. A portion of the gas left unabsorbed by caustic potassa is shaken with a solution of nitrate of silver, which absorbs phosphuretted and arseniuretted hydrogen, with the formation of a black precipitate. The presence of phosphuretted hydrogen is easily recognised by its peculiar odor, and by its producing by combustion white fumes of an acid reaction, and by its sometimes inflaming spontaneously when brought in contact with atmospheric air. Arseniuretted hydrogen deposits, when inflamed, metallic arsenic on a plate of glass or porcelain held in the flame.

96. If the gas be inflammable, but not absorbed by nitrate of silver, chlorine gas is added to it over water. This indicates, then, the presence of olefiant gas by the formation of the peculiar oil, and the ethereal odor imparted by it to the water. If the gas, after the admixture of chlorine and exposure to the action of light, is absorbed by lime-water in excess, with a turbidness, the gas may contain light carburetted hydrogen or carbonic oxide.

The two latter are distinguished from each other by heating them over mercury, after previous desiccation, with a piece of metallic potassium, which absorbs carbonic oxide, but does not act on light carburetted hydrogen. If the gas, by the addition of chlorine and exposure to light, be absorbed, but yield no precipitate with an excess of lime-water, it consists only of hydrogen.

97. If the gas explode or rekindle a glowing taper, it is then mingled with nitric oxide. If this produce red fumes, which disappear from absorption by water, oxygen is present; if, on the other hand, the admission of oxygen or atmospheric air cause red fumes, it indicates nitric oxide. The latter is also absorbed with a dark color by a solution of sulphate of protoxide of iron.

98. If, after the treatment with nitrate of silver, chlorine, and oxygen or nitric oxide, a gas still remain, it is nitrogen or nitrous oxide. By shaking it with about one-fourth of its volume of alcohol, nitrous oxide is absorbed, while nitrogen is left behind.

99. *Examination of the Gas absorbed by the Solution of caustic Potassa.* The gases absorbed by a solution of potassa are mostly of an acid nature, with the exception of ammonia, which is only absorbed as it would be by water alone. It needs hardly to be remarked that, by the presence of the latter, no acid gas could co-exist, as they would neutralize and condense each other. These gases are also sufficiently soluble in water to be separated by washing with that liquid, and the solubility of chlorohydric acid and ammoniacal gases is so great that they may be separated from all the rest by the introduction of a minute quantity of water, and subsequently recognised in this solution by their appropriate tests (nitrate of silver (45) and boiling with potassa or lime (68)). Of the rest of the gases which are absorbed by potassa, sulphuretted hydrogen and sulphurous acid cannot coexist, as they decompose each other; either of them is readily recognised by its odor; the former also by being absorbed by a solution of salts of lead, with the precipitation of black sulphuret of lead; and the latter by being absorbed by hypoxide of lead with the formation of sulphate of lead. The presence of chlorine is indicated by its color and odor, and its power of bleaching the color of litmus. It may also be recognised in the solution by caustic potassa. The presence of cyanogen is recognised after its absorption by the potassic solution, by the precipitate of Prussian blue, which it yields when mixed with a solution of sulphate of protoxide of iron, after previous neutralization with chlorohydric acid.

100. *Quantitative Estimation of Gases.* If one or more ingredients of a solid or liquid substance be gaseous, and its weight cannot be ascertained by the loss which its expulsion occasions, it is necessary to collect it and measure its whole volume. But if the substance under analysis be gaseous altogether, it is merely necessary to determine the relative quantity of the constituent gases, for which purposes one or more measured volumes of the mixture are employed. The measuring or es-

timation of the volume of gas is performed in small cylindrical tubes similar to those employed for their qualitative examination, but generally somewhat longer, and graduated into volumes. These volumes ought always, for the sake of converting them with facility into weights, to refer to a certain measure of a certain rational and decimal weight of pure water. Thus, if grain weights be employed, each volume may indicate the volume of ten grains of pure water; or if gramme weights be used, the volume of one gramme of pure water is generally made the unity volume, and called cubic centimeter. The volume of the different gaseous ingredients is generally ascertained by introducing substances into the graduated tube, by which they are absorbed, and observing the diminution in volume which is caused by them. The quantity of hydrogen and carbon contained in a gas is generally ascertained by explosion with oxygen in a eudiometer tube (see EUDIOMETER), and calculating subsequently the amount of hydrogen from the resulting diminution in volume, and that of the carbon from the quantity of carbonic acid which is formed. In the same manner, the amount of oxygen is ascertained by the diminution in volume, which takes place by its explosion with hydrogen.

101. In measuring the volume of a gas, care should be taken to preserve the same level of liquid outside and inside the tube, or to measure accurately the difference in their height, and at the same time observe the temperature of the gas and the barometric pressure of the atmosphere. The observed volume of the gas is then reduced to the normal temperature and pressure. If the gas be measured over water, a correction is also to be made for the contained vapor of water. For all these corrections, and also for the calculation of the weight of a gas from its volume, we refer to article GAS.

D. ANALYSIS OF LIQUIDS.

102. If the substance under examination be a liquid, it should first be examined by test-paper to ascertain the presence of free alkali or acid. A portion of it should then be evaporated to dryness to form some idea of its content of solid matter. It is then treated as prescribed under the analysis of solid substances, after having effected their solution. If the solution be very dilute, it may require a previous concentration; but care should then be taken that no volatile matter, as volatile acids or gases, escape during the evaporation. If this be suspected, the concentration ought to be performed in a retort with a receiver, to condense the vapors, and a tube passing from the receiver into a pneumatic trough, for the collection of the gases.

103. The natural waters, such as well, spring, sea, and the different mineral-waters, form a large group of fluids, which often become the subject of chemical analysis. These waters may of course be analyzed by evaporating a sufficient quantity, examining the gases given off, and treating the residue in accordance with the rules laid down for the analysis of solid substances; but as these waters, like the sili-

cates, have been found to contain only certain ingredients, while others never occur in them, and may, therefore, be disregarded in the examination, certain methods have been devised in order to facilitate their analysis.

104. The natural waters are generally divided into (1.) *Chalybeate* or ferruginous waters, the predominating principle of which is iron, which again are either carbonated chalybeates, containing the iron in the state of carbonate of the protoxide of iron, or sulphated chalybeates, containing the iron as sulphate. (2.) *Sulphureous* or *hepatic* waters, or those which contain in solution sulphuretted hydrogen gas. (3.) *Alkaline waters*, which are characterized by their content of carbonates or bicarbonates of the alkalies and the alkaline earths. They pass insensibly into acidulous or carbonated waters, containing an excess of free carbonic acid gas, and comparatively little of the alkaline and earthy carbonates. (4.) Saline waters, where the neutral saline ingredients are greatly predominant. Of late those waters which contain iodine have been separated into a distinct class.

105. The substances which are most commonly found in natural waters are chloride of sodium, with the chlorides of calcium and potassium, chloride of magnesium, sulphates of soda, potassa, lime, magnesia, and iron, carbonate of soda, the carbonates of lime, magnesia, protoxide of iron, sometimes with a trace of manganese, and silica. The waters of larger cities sometimes contain small portions of the nitrates of potassa, lime, and magnesia. Substances occurring rarely and only in minute quantities, are lithia, ammonia, alumina, phosphoric acid, fluorine, bromine, and iodine, besides small quantities of organic substances. The gases which are most commonly met with in them are carbonic acid, sulphuretted hydrogen, small portions of nitrogen and oxygen, and sometimes traces of sulphurous acid.

Qualitative Analysis of Mineral-waters.

106. The general character of the different mineral-waters may be readily determined by the senses. Their chief ingredients may then be ascertained by the application of different tests to separate portions of it. Some practice will also enable the operator to form at the same time a tolerably correct idea of the quantity of the different ingredients indicated by the tests from the abundance of the precipitates produced. The water is first examined in regard to its appearance, odor, and taste. Thus, the presence of sulphuretted hydrogen, even in small quantities, may easily be detected from its odor, by filling a glass half-full with the water, covering it with the hand, shaking it, and then quickly applying it to the nose. Chalybeate and saline waters are easily distinguished by their taste. Whether the water contains larger quantities of gases may be discovered by shaking it in a bottle, filled half-full with it, and then inverting it and loosening the finger so far as to observe whether any water is forced out, which may be received into a glass, and will then, from its quantity, convey an idea of the amount of the extricated

gas. A number of glasses are then filled with the fresh water, and a few more with water which has been kept boiling for a longer time, and subsequently been filtered. The following reagents are then applied to the different portions of the water:

1. *Blue Tincture of Litmus*. If a few drops of this reagent freshly prepared assume a red color when added to the water, it indicates the presence of free acid. If, after the lapse of 12 to 24 hours, the blue color be again restored, and if the same tincture, when added to a portion of the boiled and filtered water, do not change color, the presence of *carbonic acid* is indicated.

2. *Lime-water*. If, by the addition of a few drops of lime-water, a precipitate is formed of carbonate of lime, which again disappears by mixing it with the rest of the liquid, or by adding more of the water, it shows the presence of free carbonic acid or of alkaline bicarbonates. If, on the contrary, it do not disappear under the last-named circumstances, the water contains only bicarbonates of the earthy alkalies (lime and magnesia).

3. *Chloride of Barium*. A precipitate produced by the addition of a solution of this substance, after previous supersaturation with chlorohydric acid, indicates the presence of *sulphates*.

4. *Nitrate of Silver*, after previous addition of nitric acid in excess, indicates the presence of chlorides by the formation of a white precipitate of chloride of silver. Sometimes the cleared liquid assumes, after the lapse of some time, a claret color, retaining its transparency; this is caused by some organic substance. If the water contain sulphuretted hydrogen or an alkaline sulphuret, nitrate of silver causes a black or brown precipitate; in this case it is best first to precipitate the sulphur by sulphate of copper, and after the subsidence and filtration of the sulphuret of copper, to add nitrate of silver with some nitric acid, which then precipitates the chlorine as chloride of silver.

5. *Oxalate of Ammonia* precipitates oxalate of lime. If the water contain only a small quantity of lime, it requires some time before the precipitate appears. After the separation of the oxalate of lime, the addition of

6. *Phosphate of Ammonia or Soda*, with some caustic ammonia to the filtered solution, will indicate the presence of magnesia.

7. *An infusion of Galls* is used as a test for the presence of iron. In freshly drawn carbonated chalybeates no change is at first observed, but subsequently the water becomes more and more colored. A light purple color, which does not increase in the lapse of several hours, indicates a very minute quantity of iron, a larger quantity of which produces a dark purple or blackish color. In waters which contain a large amount of alkali, an infusion of galls produces a greenish or brownish color. If the infusion of galls indicate the presence of iron, but produce no color in another portion of the water that has been boiled, the iron was dissolved by carbonic acid; and if the solution in this case assume, after some hours, a green color, an alkali is present, but it must then have been kept boiling for a long

time, otherwise a content of carbonate of magnesia may produce the same effect.

The presence of the alkalies as chlorides or sulphates can generally be only ascertained by concentrating a portion of the water, precipitating the iron and the alkaline earths by a mixture of carbonated and caustic ammonia, evaporating the solution to dryness, and igniting the residue; the alkalies then remain in combination with the above acids. The alkali is generally soda; potassa is, however, sometimes found to be present. They are distinguished as described (65).

107. A thorough qualitative examination, as well as the quantitative estimation of the different ingredients of mineral-waters, can only be performed by the evaporation of a large portion of the water for the purpose of procuring a sufficient quantity of the solid residue. If possible, the gases contained in the water should be examined at the source of the water itself from freshly drawn portions. The evaporation of the water for obtaining a sufficient quantity of the salts contained in it, ought also, if possible, to be performed at the place itself, to avoid the difficulty and risk in transporting large quantities of the water, which otherwise is necessary in order to have a quantity sufficient for the examination for the more rarely occurring substances. During the evaporation of the water the same salts precipitate which are deposited by contact of the water with the atmosphere. These may, if desirable, be separated by filtration of the deposit from the concentrated solution, after which the soluble salts may be evaporated to dryness by themselves. This method is better than to treat the dry residue with water, as by the evaporation to dryness, salts are rendered insoluble which would not separate from the solution. But the best plan is to ascertain whether the water do not form at its sources spontaneous deposits, which should be procured and examined carefully by themselves, as they often contain substances which might escape our notice by the examination of the water, on account of the minute quantity in which they are contained in it. When collecting the water in bottles, its temperature at the time ought to be noted, and care taken to seal the bottle perfectly air-tight. A good and well secured cork will keep perfectly air-tight by itself, while it is mostly impossible to attain this object by any means, if the cork be imperfect.

Quantitative Analysis of Mineral-waters.

108. *Alkaline and Carbonated Waters. Analysis of the fixed Ingredients.* To measure the different portions of water required for analysis, a stoppered glass bottle may conveniently be used, having first ascertained accurately by weight the quantity of water which it holds. This bottle is also used for taking its specific gravity.

a. To ascertain the quantity of fixed ingredients, one or more measures are evaporated to dryness in a platinum or small porcelain capsule, previously counterpoised and heated strongly. If it contain organic matters, the heat should be high enough to incinerate them. The weight of the remaining mass is then

ascertained with accuracy. If the water contain very few fixed ingredients, and it consequently should become necessary to use a large capsule for the evaporation of a sufficient quantity, the concentrated solution and the residue should, towards the end of the evaporation, be transferred into a small crucible or small capsule for the purpose of weighing it, but it is then almost impossible to remove, by any mechanical means, the adhering portion.

b. The residue is treated with water, and what remains undissolved collected on a counterpoised filter, washed, dried, and weighed on the filter. It consists principally of silica, carbonate of lime and magnesia, and peroxide of iron, which have been kept in solution by carbonic acid. It more rarely contains traces of phosphoric acid and fluorine.

c. By deduction of the weight of the insoluble salts from the whole residue, the weight of the soluble salts is obtained. The latter consist mostly of carbonate of soda, with smaller portions of chloride of sodium and sulphate of soda. They sometimes also contain some potassa and traces of lithia. The solution is supersaturated with chlorohydric acid, evaporated to dryness, cautiously ignited, and weighed. If it be desired to examine it for potassa, it is redissolved, chloride of platinum added, the solution evaporated nearly to dryness, and treated with alcohol. If any chloroplatinate of potassium remain, its weight is ascertained by collecting it on a counterpoised filter, and the amount of potassa computed from it.

d. For estimating the sulphuric acid, a measured quantity of the water is mixed with chlorohydric acid in excess, and precipitated by a solution of chloride of barium. The sulphate of baryta is filtered, washed, and weighed, and the quantity of sulphuric acid computed from it.

e. Another measured portion of the water is supersaturated with nitric acid and precipitated with nitrate of silver. The chloride of silver is collected on a counterpoised filter and weighed, and its equivalent of chlorine or chloride of sodium computed.

f. The potassa is generally considered as combined with its equivalent of sulphuric acid, the rest of which is then calculated as combined with its equivalent of soda. Having calculated from the known weight of the potassa, sulphuric acid, and chlorine, the quantities of sulphate of potassa and soda, and chloride of sodium, and deducted their joint weight from the weight of the whole of the sulphates and chlorides obtained in c, the difference is chloride of sodium, equivalent to the amount of carbonate of soda contained in the water, which, therefore, is calculated from it.

g. The salts remaining insoluble by treatment of the residue with water (b) are dissolved in nitric acid, evaporated to dryness, and redissolved in water, after previous moistening with a few drops of nitric acid. The silica then remains insoluble, and is separated by filtration, ignited, and weighed. The filtered solution is precipitated by caustic ammonia in excess, and filtered rapidly. The precipitate

consists chiefly of peroxide of iron, but may also contain small portions of phosphoric acid, alumina, manganese, and phosphates of magnesia and lime. If it be not desired to estimate the quantity of these substances, it is ignited and weighed. The filtered solution is mixed with oxalate of ammonia, by which the lime is precipitated as oxalate of lime, which is filtered and by ignition converted into carbonate of lime and weighed, and from it the quantity of lime calculated. The filtered solution from the oxalate of lime is evaporated to dryness and ignited, to expel ammoniacal salts and nitric acid from the magnesia, which is then weighed. The magnesia may, however, contain traces of manganese and carbonate of soda. The latter is extracted by water, its weight ascertained by evaporating to dryness and ignition, and deducted from that of the magnesia.

If the water has been kept in bottles, peroxide of iron and more or less of the earthy carbonates are apt to precipitate on the inside of the bottles. The deposit is removed by a small portion of nitric acid, and either analyzed separately or added to the solution of the insoluble salts in nitric acid.

Estimation of the Gases. Small quantities of oxygen and nitrogen are generally found dissolved in these waters; but it is more especially the carbonic acid, the quantity of which it is desirable to know. It occurs partly combined with the bases as bicarbonates, partly in its free state. The quantity in combination with the bases is obtained by precipitating a certain measure of the water with a solution of neutral nitrate of lead in excess, collecting, filtering, and washing the precipitate, and determining its content of carbonic acid, as described (88).

The quantity of carbonic acid thus obtained gives, when doubled, the quantity contained in the bicarbonates. To estimate the quantity of free carbonic acid, an equal quantity of water is precipitated with a solution of basic acetate of lead in a closed bottle. The precipitate is allowed to subside, and must be collected and washed so as to prevent it from attracting carbonic acid. Its content of carbonic acid is then determined while still wet, as in the former case. If, then, the quantity of carbonic acid in the bicarbonates be deducted from the quantity obtained in this last experiment, the difference is the quantity present in its free state.

109. Saline Waters. The amount of fixed ingredients is determined in the same manner as in the former waters. As the greatest part of the magnesia in these waters is present as chloride of magnesium, it loses hereby its chlorine and is converted into magnesia, which remains insoluble. The analysis of the fixed residue may be conducted as in the former case, only with such modifications as may be required on account of the greater quantity of sulphates and chlorides. The usual method of separating the salts by alcohol is of no advantage.

110. Hepatic Waters. The fixed ingredients are determined as in other waters. The sulphur, which in these waters is the most important, may exist as sulphuretted hydrogen

and as a soluble sulphuret. The whole quantity of sulphur which they contain is estimated by mixing a measured quantity of the water with a solution of nitrate of silver, and sufficient ammonia to prevent any chloride of silver from being precipitated. The precipitate, which consists of sulphuret of silver, may also contain earthy carbonates. It is collected on a counterpoised filter and successively washed with ammonia, acetic acid, and pure water, after which the remaining sulphuret of silver is dried on the filter and weighed, and from it the amount of sulphur computed. To ascertain the quantity of free sulphuretted hydrogen, a measured quantity of the water is kept boiling for some time, filtered, and the quantity of sulphur which it then contains determined as before. Deducting the quantity thus obtained from the former, the difference gives the amount of free sulphuretted hydrogen.

II. ANALYSIS OF ORGANIC SUBSTANCES.

111. Under the name of organic substances chemistry comprises all those substances which are either immediate products of vegetable or animal life, or obtained from them by subsequent treatment with chemical reagents. A great number of the former are sometimes distinguished from the latter by the names of organized substances, when they retain some inner structure from the manner in which they were deposited or formed in the organic body. In organic as in inorganic chemistry, we distinguish between proximate and ultimate constituents; but in regard to the immediate products of organic life, such as different parts of animals and plants or their fluids, which consist of a mechanical mixture of a number of substances, these ingredients are often incorrectly termed their proximate constituents.

112. Organic substances are either acids, bases, and their salts, or neutral substances, in which neither the character of acid nor of base predominates, and which cannot be proved to be salts or to be formed by the combination of any proximate constituents. The substances which are most apt to become the subjects of an analysis, with a view to determine their proximate constituents, are mostly parts of animals or plants or their fluids, or artificial mixtures of organic substances, which are employed in medicine or in manufactures and arts.

113. The organic bases are almost exclusively obtained from plants, and therefore generally called vegetable alkalies. The method employed to discover them is to extract the substance with water to which sulphuric or chlorohydric acid has been added. The solution is then neutralized with caustic ammonia and mixed with a solution of tannin as long as any precipitate is formed. The precipitate is washed, mixed with hydrate of lime, and dried. It is then boiled with anhydrous alcohol, which dissolves the organic base, and deposits it on cooling or by evaporation.

114. Organic Acids. The plurality of these is also derived from the vegetable kingdom. They are mostly found in the juices, either in

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their free state or in combination with inorganic bases, more rarely with a vegetable alkali; many of them are used extensively in medicine and in manufactures and arts, and are therefore often met with. The method generally used for their separation from plants or vegetable products, is to procure the juice of the plant, or to make an infusion of the substance in water to which a small portion of carbonated alkali has been added, to filter the solution, neutralize it, and then precipitate it either by a salt of lime, or neutral or basic acetate of lead, according to the greater or less solubility of the salts of the acids with these two bases. In the first case the obtained salt of lime may be decomposed and the acid obtained in solution, by treatment with alcohol to which sulphuric acid is added in small portions, avoiding an excess. In the two latter cases the acid is liberated by decomposing the salt of lead by sulphuretted hydrogen. The solution of the acid is either evaporated to crystallization, if it be crystallizable, or neutralized by a base with which it forms a salt that is easily crystallizable. The acid or its salt is often purified previous to its crystallization by boiling with animal charcoal. If the acid do not form an insoluble salt with lime or lead, other extraneous substances may be separated by precipitation with their salts, when the acid remains in solution, and may subsequently be separated and purified in the same way. Having obtained the acid or one of its salts in a pure state, it may then be recognised or studied by its peculiar properties.

115. The following list comprises some of the organic acids of most frequent occurrence:

- | | |
|----------------|-------------------|
| 1. Oxalic acid | 6. Succinic acid. |
| 2. Tartaric " | 7. Acetic " |
| 3. Citric " | 8. Formic " |
| 4. Malic " | 9. Tannic " |
| 5. Benzoic " | 10. Gallic " |

Some of these acids are extensively used in medicine as well as in manufactures and arts, and are therefore often met with in artificial preparations or mixtures. The best way of recognising them in such is to transfer them to one of the alkalies, if they are not already combined with them, by boiling with carbonate of soda or potassa. Thus a solution of the acid with the alkali is obtained, which, after careful neutralization of the excess of the carbonated alkali with an appropriate acid, may be tested with the different reagents.

116. The first four of the above-named acids are distinguished from each other by the behavior of their salts with lime. After their transfer to an alkali, and perfect neutralization of the solution by chlorohydric acid and the addition of some chloride of ammonium, a solution of chloride of calcium is added. If no precipitate be produced, or only after the lapse of some minutes, it indicates the absence of oxalic and tartaric acids; but if a precipitate appear immediately, it indicates the presence of one or both of them. If a portion of the precipitate be charred, the presence of tartaric acid will be indicated by the great abundance of separated carbon, and the peculiar odor it exhales during its charring. The presence of

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oxalic acid is ascertained by the immediate appearance of a precipitate on adding a solution of gypsum to the original solution.

117. The solution to which chloride of calcium has been added, which must be filtered if a precipitate was formed, is then heated to ebullition. If it remain clear, citric acid is absent; but if it become turbid and deposit a precipitate, the presence of this latter acid may be inferred.

118. Malic acid is under none of these circumstances precipitated by a solution of chloride of calcium; but if the original solution be saturated with acetic instead of chlorohydric acid, and acetate of lead added, it forms a white precipitate of malate of lead, which, after the lapse of some time, loses its amorphous character and is converted into groups of crystalline needles, and which, when thrown in mass into boiling water, assumes a soft, gummy or resinous character.

119. Succinic and benzoic acids are distinguished by the readiness with which they sublime in their free and dry state, and by the flocculent precipitate which their neutral alkaline salts yield with a solution of perchloride of iron. They are distinguished from each other by their different solubility in water, which causes the benzoic acid to separate as a more or less minute crystalline precipitate, by the addition of chlorohydric acid to a moderately strong solution of its alkaline salts. The succinates of the alkalies are also insoluble in alcohol, while the alkaline benzoates are soluble in it. Succinic acid generally retains some odor of oil of amber, which, in some cases, may lead to its detection.

120. Acetic and formic acids are easily distinguished by their volatility and odor, when liberated, by the addition of sulphuric acid, after which they are easily separated by distillation. They are then easily distinguished from each other by digestion with red oxide of mercury; the latter is immediately reduced to metallic mercury by the presence of formic acid, while the presence of acetic acid is recognised by digestion with oxide of lead, with which it forms a soluble basic acetate of lead, which exhibits a strong alkaline reaction on red litmus paper.

121. Tannic and gallic acids are at once recognised by the dark bluish or greenish black precipitate, which even dilute solutions of them or their salts yield with salts of peroxide of iron. They may be distinguished from each other by a solution of sulphate of quinine, which precipitates tannic but not gallic acid. If, therefore, no precipitate be formed by sulphate of quinine, or if, after complete precipitation of the tannic acid by it, the filtered solution still yield the characteristic color with salts of iron, the presence of gallic acid is indicated. The separation of tannic acid may also be effected completely by a piece of raw hide prepared for tanning.

122. *Of neutral or indifferent organic Substances.* Lignin is recognised by its insolubility in all neutral solvents, as well as in dilute acids and alkalies. Starch is generally recognised by its insolubility in cold water, its solubility in hot water, and the blue color which it

produces with iodine; *gum* by its glutinous character, its solubility in water, and insolubility in alcohol; the different varieties of *resins* by their insolubility in water and their solubility in alcohol of different strengths; the different *oily* and *fatty matters* by their insolubility in water and weak alcohol, and their solubility in anhydrous alcohol or ether; the essential oils by their odor and their volatility, when distilled with water and alcohol. Of the most common nitrogenized substances of this class, *glue* is marked by its solubility in hot water and its gelatinizing from the solution on cooling; *soluble albumen* by its coagulation by heat and by alcohol; *coagulated albumen*, as well as the rest of the protein compounds, among other properties, by their precipitation by ferrocyanide of potassium when dissolved in dilute acids, &c., &c.

123. The method generally employed for the analysis of parts of plants and animals, consists in subjecting them to extraction with a series of neutral solvents or chemical reagents, such as ether, alcohol of various strengths, water, both cold and hot, dilute acids and alkalis. The substance is first dried and reduced to a coarse powder, and then the operation of extraction with the different solvents, most conveniently performed by a small displacement apparatus (see *EXTRACT*), or in a corked bottle, using small portions of the solvents at the time, and repeating it with fresh portions as long as anything is dissolved. The different solutions thus obtained are evaporated to dryness in order to ascertain the quantities dissolved, and these residues again examined and separated into the different substances which they may contain.

Ultimate Organic Analysis.

124. Organic substances consist only of a few ultimate elements, which, by combining in different but fixed proportions, form the great variety of this class of substances. Much the greater number contain carbon, hydrogen, and oxygen, and many also nitrogen. The presence or absence of the latter element marks them off into two distinct and well characterized classes, nitrogenized and non-nitrogenized substances. A qualitative examination, with a view to determine their ultimate elements, is therefore rarely called for, except in regard to the presence of the last-mentioned element. Some organic substances contain sulphur and phosphorus, and most of the immediate products of organic life always contain some inorganic ingredients which can only be separated from them by incineration, and are called their ashes.

It will be evident from the foregoing remarks that ultimate analyses, either qualitative or quantitative, are of little use in determining the proximate constituents of organic substances, or their identity with known substances, unless they have been obtained in their perfectly pure state. The main object of the ultimate analysis of an organic substance is generally to determine with accuracy the quantity of its different elements, and from that the relative number of atoms which enter into its composition.

125. In estimating the quantity of the ultimate elements, nitrogen is the only one, the quantity of which is still determined in its free or gaseous state. The methods employed have all for their object to effect a complete combustion or oxidation of the substance, so as to convert all its carbon into carbonic acid and its hydrogen into water, and to determine the quantity it yields of these two substances, from the known composition of which the quantities of carbon and hydrogen are computed. If the substance contain nitrogen, this is liberated and either collected at the same time, its quantity being determined by measuring its volume, or a separate analysis performed, with a view to determine the quantity of this element alone, either directly by measurement or by the quantity of ammonia which it may be made to yield, as will be presently described. The content of oxygen is in every case estimated by loss, or the difference between the weight of the substance and the joint weight of its other elements.

126. To effect the combustion of the substance, various methods have been adopted. Gay-Lussac and Thenard, who performed the first successful elementary analyses of organic substances, mixed the dry substance and chlorate of potassa in weighed quantities, made them by water into a soft mass, and formed them into small pills, which again were dried. The quantity of the substance and of chlorate of potassa, which a certain weight of them contained, was thus known, and also the quantity of oxygen contained in the latter; this having been ascertained by a separate experiment before its mixture with the substance. To effect the combustion of these pills, they employed an apparatus consisting of a glass tube sealed at its lower end, and its upper extremity mounted by a brass cock, the key of which was not perforated, but had only an excavation sufficiently large to receive one of the pills, and drop it on being turned half-round into the lower end of the glass tube, which was kept at a low red-heat, and where the deflagration then took place. The generated gases were carried off by a lateral tube, inserted below the cock, and were received in a graduated bell-glass over mercury. Before beginning the analyses, a number of pills were deflagrated merely for the purpose of expelling the atmospheric air from the apparatus, and filling it with the same mixture of gas as produced by the deflagration, in order to avoid subsequent deductions and corrections. A weighed quantity of the pills were then introduced, and the quantity of gas which they yielded carefully collected and measured, and its relative proportion of carbonic acid and oxygen ascertained by absorption with caustic potassa. The whole quantity of carbonic acid and oxygen yielded by a certain quantity of the substance and chlorate of potassa, being thus known, the amount of water formed by the combustion was ascertained by deducting the joint weight of the obtained carbonic acid and oxygen from the joint weight of the substance and the oxygen contained in the quantity of the chlorate of potassa mixed with it. The carbon and hydrogen were then computed

from the obtained amounts of carbonic acid and water. Deducting the oxygen in the chlorate of potassa from the joint weight of the free oxygen in the obtained mixture and that in the carbonic acid and the water, the difference yielded the amount of oxygen contained in the substance. By this method Gay-Lussac and Thenard analyzed 19 organic substances, viz.: 15 vegetable compounds, acetic, oxalic, tartaric, citric, and mucic acids, common sugar, sugar of milk, gum, starch, oak and beech wood, olive oil, wax, copal, and white turpentine (resin); and 4 animal substances: fibrin, albumen, casein, and glue. Experience has shown that with proper care correct results may be obtained by this method.

127. But as, by deflagration, portions are apt to escape perfect combustion and condense on the cooler parts, Berzelius tried to avoid this inconvenience by a slow and more perfect combustion, for which purpose he employed a mixture of chlorate of potassa and chloride of sodium, with which the whole quantity of the substance was mixed, and introduced into a glass tube, and this then heated slowly in a horizontal position from one end to the other. He also introduced the improvement of collecting and absorbing the generated water in a separate vessel, and thereby was enabled to ascertain directly its weight with great accuracy, which is of the greatest importance, on account of the small atomic weight of the hydrogen. As chlorate of potassa could not be employed with advantage in the combustion of nitrogenized substances, on account of the readiness with which it gives off its oxygen by mere heat, and the consequent formation of nitric acid from the nitrogen; the introduction by Gay-Lussac of oxide of copper instead of chlorate of potassa, formed another great improvement. Finally, the invention of Liebig's potassa bulbs, by which a complete absorption of the carbonic acid is effected by a solution of caustic potassa, and thereby all collection of gases dispensed with in the analysis of compounds of carbon, hydrogen, and oxygen, and the lately invented method, by Varrentrapp and Will, of converting the nitrogen of nitrogenized substances into ammonia, and absorbing it by an acid, thus also dispensing with pneumatic operations in the analysis of nitrogenized compounds, have given to the ultimate analyses of organic compounds a high degree of perfection, and made them comparatively easy of execution.

Instead of performing the combustion by heating the tube in a small furnace by a charcoal fire, several attempts have been made to perform this operation by the aid of spirit-lamps; but notwithstanding there is less nicety in the use of charcoal, nothing has yet been found to answer equally well.

128. Among other methods of effecting the combustion of organic substances, that of Prout may be mentioned, which consists in performing the combustion in a measured volume of oxygen. As carbon, by its combustion in oxygen gas, does not alter the volume of the latter, but hydrogen, by the formation and condensation of water, causes half of its volume to disappear, it will be evident that if

the combustion of a substance consisting only of carbon, hydrogen, and oxygen, be performed in oxygen, it will not alter the volume of this latter, if its hydrogen and oxygen be exactly in the proportion necessary to form water; but that if it contain more hydrogen, this excess will cause a diminution of the oxygen equal to half its volume; and if it contain an excess of oxygen, this will be employed for the conversion of a portion of the carbon into carbonic acid, and consequently produce an increase of the volume of the oxygen equal to its own volume. If, therefore, the volume of the oxygen be measured before and after the combustion, and also the quantity of carbonic acid formed, it is possible from this and the known weight of the substance to compute its exact composition.

129. We shall now give a more detailed description of the method of Liebig and the apparatus which he employs for this purpose, with a few remarks of Berzelius on several of his peculiar arrangements.

The apparatus of Liebig will be understood from Fig. 2, Plate I.; *a* is the combustion-tube, in which the substance to be analyzed is introduced after its mixture with oxide of copper or chromate of lead, from which it obtains the oxygen necessary for its combustion. The figure represents the tube in its position during the analysis in the trough-shaped furnace of sheet-iron, in which it is heated by being surrounded with ignited charcoal. By means of a perforated cork, the combustion-tube is connected with the tube in which the water produced by the combustion is condensed. It is filled with chloride of calcium in order to absorb all the vapors from the carbonic acid, which passes through it, into the apparatus, *m r p*, through which it would be forced, were it not absorbed by the solution of caustic potassa contained in the lower bulbs. After the completion of the combustion, the carbonic acid which remains in the combustion-tube is extracted from it, by breaking off its pointed extremity and applying suction to the other end of the potassa apparatus at *p*, by which air is drawn through the whole apparatus, and the carbonic acid absorbed by its passage through the solution in the potassa bulbs. The weight of the water and the carbonic acid is obtained by weighing the chloride of calcium tube and the potassa apparatus before and after the combustion.

130. *Desiccation of the Substance.* An essential operation before beginning the analysis of a substance is to obtain it in its perfectly dry state. Most organic substances absorb hygroscopic moisture from the air, from which they can only be freed by heating them to a certain temperature, usually that of boiling water, either in vacuo or in a current of dry atmospheric air. Liebig employs a contrivance as seen in Fig. 1, Plate II. It consists of the glass apparatus *a*, which is immersed into a vessel containing boiling water, the substance to be desiccated being contained in its larger horizontal portion, having about half inch in diameter, to which are attached by the blowpipe two smaller tubes bent upward, one larger for the introduction of the substance, and connected, by

means of a perforated cork, with a tube containing chloride of calcium, the end of which is seen at *c*, and another smaller one bent at its upper extremity, at right angles, to connect it with the tube *d*. The use of the three-necked Woulfe's bottle is to produce a suction, and, consequently, a current of air to pass over the substance. It has the three tubes inserted airtight, by means of perforated corks, into its three necks; the funnel-tube serves to fill and replenish the bottle with water; the object of the syphon-tube is to drain the water out of the bottle and thereby force air to enter through the tube *d*, whose lower extremity terminates about an inch higher than the lower end of the outer limb *e d* of the syphon. Filling the latter with water by suction with the mouth at *a*, the draining of the water from the bottle is commenced, and a current of air passed through the whole apparatus. As the air must enter through the tube *c* filled with chloride of calcium, it is perfectly desiccated before it reaches the substance heated in the desiccating apparatus, by being surrounded by boiling water, and readily removes all the moisture given off by it. As long as any moisture is seen to condense at *d*, it is a proof that the desiccation is not yet completed. As a proof of the latter, Liebig prescribes introducing a small portion of it into a narrow tube, see *a*, Fig. 8, Pl. I., and heating the end of the tube by a small spirit-lamp, or in a sand-bath, taking care not to expose it to a temperature at which it is decomposed. If any moisture then appear to condense in the colder part of the tube at *b*, it proves that the desiccation is not complete, and the apparatus must often then be heated in a solution of chloride of calcium or in a sand-bath, instead of boiling water. In cases where the substance retains its water with great tenacity, it is sometimes necessary to heat it in vacuo. For this purpose the substance is introduced into a strong cylindrical test-tube, which is connected with an air-pump by an interposed tube containing chloride of calcium. The test-tube is heated in a bath of chloride of zinc, having a thermometer immersed in it to indicate the temperature. By alternately exhausting and admitting the air into the test-tube, it dissolves the moisture given off by the substance, and deposits it on its passage through the chloride of calcium tube.

131. *Weighing.* Having obtained the substance in a perfectly dry state, care must be taken to prevent it from absorbing moisture again by exposure to the atmosphere during the subsequent weighing. The weighing is therefore best performed in a narrow test-tube (see p. 169, Fig. 9). The quantity of the substance employed for analysis depends on different circumstances, and generally varies from 0.3 to 0.6 grammes. A portion, as near as can be judged to be the desired quantity, is quickly introduced into the counterpoised test-tube and its weight ascertained accurately. In mixing the substance with oxide of copper or chromate of lead, the portion adhering to the tube is carefully rinsed out with a portion of these last-mentioned substances and added to the mixture; or the tube may be returned to the

balance, and the weight of the adhering portion ascertained and deducted.

132. *Oxide of Copper.* The material most usually employed to effect the combustion is the oxide of copper. It may be prepared by dissolving strips of pure sheet-copper in pure nitric acid, evaporating the solution to dryness in a porcelain evaporating dish, and igniting it in a covered hessian crucible. During the ignition the oxide must be stirred with an iron or copper rod. After the ignition it is finely pulverized, and kept in well-stoppered bottles. Oxide of copper which has been used for analysis is again restored by ignition after previous moistening with nitric acid. After the analysis of an organic salt of the alkalis or the alkaline earths, these must of course be first extracted by digestion with some dilute nitric acid and subsequent washing with boiling water. Dumas prepares the oxide of copper by calcination of thin sheet-copper in a muffle, which furnishes a compact and, for many purposes, superior oxide. A mixture of coarse and pulverulent oxide is conveniently made by preparing the dry nitrate, breaking it in pieces, interstratifying it with clippings of sheet-copper, the nitrate being in excess, and heating it in a hessian crucible to a bright redness. After cooling, it may be moistened with nitric acid and again heated to a full red. The mass then consists of pulverulent and granular black oxide, and metallic copper, the latter of which may be separated from the oxides by breaking and sifting.

133. *Chromate of Lead.* For the analysis of substances which contain a large amount of carbon, such as coals, &c., a complete combustion cannot be obtained by oxide of copper, unless a mixture of chlorate of potassa and oxide of copper be introduced in the back part of the combustion-tube, by which oxygen is given off at the end of the operation. For the combustion of such substances chromate of potassa is preferred, since it contains in the same volume a much larger quantity of oxygen. It has also the advantage of not attracting hygroscopic moisture. It is used in the quantity of somewhat more than half the volume that would be required of oxide of copper. It is prepared by precipitating a solution of bichromate of potassa with acetate or nitrate of lead, and washing the precipitate carefully with hot water. After drying it is heated in a covered crucible till it begins to soften, and then subsequently pulverized finely. Its yellow color is changed by ignition into a brown. It may be substituted in all cases for oxide of copper.

134. *Combustion-Tubes.* The tubes used for combustion should be of a hard, potash glass, containing no oxide of lead and very difficult of fusion. Those made in Bohemia are recommended as the best. They should be a little less than half an inch in diameter. Before using them they should be thoroughly cleaned by washing with water, and dried perfectly by drawing air through them with the mouth, while the other end is heated. The one end is then cut off square, and the edges rounded in the fire for the purpose of receiving the cork that connects it to the chloride of calcium tube, while the other end is drawn out to a point

which is turned upwards and sealed as shown in Pl. I., Fig. 2. The length of the tube thus prepared should be from 15 to 17 inches. During the combustion it always should be surrounded by a tube of thin sheet-copper or iron fastened round it, by a few pieces of twisted iron-wire.

135. The shape of the *chloride of calcium tube* for the collection of the water is seen from *b*, Fig. 2. At the one end it terminates in a narrow tube, which is fitted into the combustion-tube by means of a perforated cork. Care should be bestowed in the selection of a cork free from imperfections. Before filling it, it is squeezed in a cork press to render it soft. The perforation should be made by a round file, and the outside cut by a sharp knife. Liebig prescribes that it should fit tightly, and that it, previous to the analysis, should be heated in a crucible by a sand-bath to a pretty high temperature, in order to free it from hygroscopic moisture. The bulb of the chloride of calcium tube is filled with larger fragments of strongly dried but not fused chloride of calcium; the rest of the tube is filled with coarse powder of the same substance, and closed by a well-fitting perforated cork, having a small piece of glass tube inserted in its centre, in order to connect it with the potassa apparatus. Liebig prescribes covering the cork with sealing-wax. The chloride of calcium is prevented from getting out at either of the extremities by a plug of loose cotton. Before the analysis, the whole tube is weighed accurately, which may be done conveniently by suspending it to the balance by a piece of thin wire, twisted in its middle into a hook or loop, and at its two extremities into hooks to receive the two extremities of the tube. The increase of the weight after the analysis is the amount of water yielded by the combustion.

136. The *potassa apparatus* is connected with the chloride of calcium tube by a small caoutchouc tube (see *Caoutchouc*). It consists of a small glass tube, on which are blown 5 glass bulbs, 3 of them close together in the middle and one on each side at some distance from them; and the whole then bent in the shape as represented by *m r p*, fig. 2. It is partly filled with a solution of caustic potassa of spec. gravity 1.25 to 1.27, by immersing one end into a vessel containing the potassic solution, while suction with the mouth is applied to the other end, with the intervention of the tube *B*, fig. 3, to prevent the possibility of some of the solution being drawn into the mouth. The potassic solution should fill the three lower bulbs, with the exception of a small air-bubble in each of them, but should not be contained in the two upper ones. The whole apparatus is weighed before and after the analysis. The increase in weight gives the amount of carbonic acid yielded by the combustion. During the weighing the apparatus may be suspended from the balance by a hook of wire, attached where the small tubes cross each other.

137. The furnace in which the combustion-tube is heated is made of sheet-iron. It is from 22 to 24 inches long, 3 inches high, $4\frac{1}{2}$ inches wide at the top, and 3 inches at the bottom; the

latter is provided with transverse slits (see fig. 3) about half an inch apart, forming a kind of grate. Between the slits perpendicular pieces of strong sheet-iron are riveted to the bottom, at certain intervals, for the purpose of supporting the combustion-tube on their upper edges, which are therefore excavated, and have all exactly the same height, corresponding with the round aperture in the front of the furnace for the admission of the combustion-tube. The furnace is placed on fire-bricks, the first slit in front projecting so as to be open, but the rest closed. The fire-bricks are supported on a block of wood, the further end of which may be slightly raised by a small wedge. The moveable screen *g*, fig. 2, serves to confine the fire and protect the part of the tube that is not yet ignited. It is made of a double piece of sheet-iron, fitting exactly across the furnace, and having slits for the accommodation of the combustion-tube. The fuel employed for the ignition is good charcoal, which ought to be broken in pieces of from 1 to 2 cubic inches in size, and separated from the smaller pieces by a sieve. When an analysis is to be performed, a sufficient quantity is kept ignited in a furnace, from which they are readily transferred to the combustion furnace.

138. In commencing an analysis, after having all the above materials and apparatus ready, and the substance to be analyzed desiccated, a portion of the latter should be weighed and mixed with the necessary quantity of oxide of copper. The latter ought to have been freshly ignited, and allowed to cool in a bell-glass over sulphuric acid, or been introduced while yet hot in a well-stoppered bottle. To have a measure for the quantity required for the mixture, the combustion-tube is filled with it to about $\frac{3}{4}$ of its length. A portion of the oxide is then shaken out into a mortar, and the weighed portion of the substance mixed with it, removing all particles adhering to the tube by rinsing with different portions of oxide of copper. The mortar employed for the mixing should be of porcelain, and have its inner surface smooth, but not glazed. Before using it, it should be previously heated and rinsed out with some oxide of copper, which is not mixed with the rest. After the substance has been thoroughly mixed with a portion of the oxide of copper, the rest is added and mixed with it. To guard against any spilling during the mixing, the mortar should be placed on a sheet of glazed letter-paper. Having first introduced into the bottom of the combustion-tube about half an inch of pure oxide, the mixture of the substance with the oxide is next filled into it, which is best done by the aid of a funnel with a wide neck, made for the purpose, and the mortar and pestle rinsed out 2 or 3 times with small portions of oxide, which are added on top of the first mixture, and then the rest of the tube filled with pure oxide till within an inch of its mouth.

139. During this operation the attraction of some hygroscopic moisture cannot be prevented; and as this would influence the accuracy of estimating the hydrogen, it is necessary to remove it before beginning the analysis. This is done by surrounding the combustion-

tube in a wooden trough, D, Fig. 1, with sand of the temperature of 250° , having previously produced a passage between the oxide of copper and the upper side of the tube through its whole length, by gentle tapping of the tube in a horizontal position, and then connecting it by means of a tube, B, containing chloride of calcium, with an exhausting-syringe. By alternately exhausting and admitting the air for 10 or 12 times into the combustion-tube, the moisture given off by the contents of the tube is dissolved and deposited on its passage through the chloride of calcium.

140. During the foregoing operation the weighing of the chloride of calcium tube and the potassa apparatus may conveniently be performed. Having then restored, if necessary, the free passage over the oxide for the escape of the gases generated during the combustion, the combustion-tube is next surrounded by thin sheet-copper, if thought necessary, and adjusted in the furnace in a horizontal position or inclined slightly forward, and projecting an inch out of the furnace, as seen in Figs. 2 and 3. The chloride of calcium tube is then attached to it by its perforated and previously desiccated cork. Its position should also be inclined slightly forward, in order to allow the water condensing in its narrow extremity to run into the bulb. Its other extremity is connected by a small caoutchouc tube with the potassa apparatus. The latter may be rested on a folded towel, and its extremity at *r*, Fig. 2, slightly elevated during the combustion by a piece of cork, *s*. Before beginning the combustion, it is necessary to ascertain that all the connections are tight, by sucking out of the apparatus a bubble or two of air by means of the tube B, Fig. 3, fixed to the open end of the potassa apparatus by a perforated cork. By this slight rarefaction of the air in the apparatus, the potassic solution is caused to rise about one and a half inch higher in the bulb at *m* than in the opposite bulb. If this difference of level remain unchanged for some time, the apparatus may be considered tight, otherwise there is a leak which must be corrected.

141. The combustion is commenced by surrounding the anterior portion of the tube, containing only oxide of copper, with ignited charcoal, protecting the rest of the tube by the screen *g*, Fig. 2. When the anterior portion of the tube has become red-hot, the screen is gradually moved backwards half an inch or an inch at the time, filling the space immediately with red-hot coals, so as to raise the temperature of the successive portions of the tube at once to a red heat, for which purpose a fan may also be advantageously employed. It is sometimes necessary to place a screen immediately inside the front of the furnace, to prevent the cork from being burned, while, on the other hand, if any water be seen to condense in the protruding portion of the tube nearest the cork, it should be prevented by a few ignited coals placed below it. The combustion is thus proceeded with, taking care to keep up a slow but steady evolution of gas, till the screen, in the course of from 20 to 30 minutes, has been moved to the other end of the tube, and the combustion is completed. If the latter

have been well performed, the evolution of gas generally ceases suddenly. The fire should then be brightened up through the whole length of the tube, either by fanning or by raising the furnace slightly from the bricks by two flat pieces of iron; but the heat ought never to be allowed to rise above a dull red heat.

142. As soon as the evolution of gas ceases, the potassic solution begins to rise into the bulb, *m*, from the absorption of the carbonic acid gas contained in the apparatus. The charcoal is then removed from the outer end of the furnace, and the pointed end of the combustion-tube broken off by a pair of pliers, and the open tube *h*, Fig. 3, from 12 to 15 inches long, attached by a perforated cork to the opened end. The potassa absorbs, then, in the lapse of a few minutes, nearly all the carbonic acid in the apparatus, which is replaced by atmospheric air through the tube *h*. To complete the absorption, the suction-tube B is applied to the open end of the potassa apparatus, and by the mouth, so much air as would be equal to about twice the capacity of the whole apparatus, slowly drawn through it. All the vapor and carbonic acid that still remain in the combustion-tube are thus carried into the chloride of calcium tube and the potassa apparatus, and completely absorbed. The potassa apparatus and the chloride of calcium tube are then removed and weighed.

143. By the analysis of highly carbonaceous substances with oxide of copper, some carbon is apt to remain unoxidized, which, according to Liebig, is completely oxidized by the subsequent suction of atmospheric air through the tube while it is still ignited. In such cases, it is, however, better to employ chromate of lead. The inconvenience may be avoided, even with oxide of copper, by introducing at the sealed end of the tube a mixture of one part of cautiously fused and pulverized chlorate of potassa and 8 parts of oxide of copper. This mixture causes, at the end of the combustion, an evolution of oxygen, by which the remaining carbon is oxidized. Liebig remarks that if, by the suction of air through the apparatus, no empyreumatic taste be perceived, the combustion has been perfect. If otherwise, it does not indicate positively that the analysis has been unsuccessful, since two analyses will often yield exactly the same results, though in one case an empyreumatic taste be perceived, and none in the other.

144. To the foregoing methods, as practised by Liebig, and described by him in his pamphlet on organic analysis, Berzelius has made some objections in the 7th volume of his Chemistry. In the first place, he rejects the use of a cork for connecting the combustion-tube with the chloride of calcium tube, on account of its hygroscopic properties, stating that if the cork be previously dried, it absorbs moisture during the combustion, which cannot be expelled by heating the cork from the outside. To avoid the use of the cork, Berzelius draws the combustion-tube out before the blowpipe-lamp, giving it first a bend upward and then downward, to prevent the oxide of copper from falling out, and connects it with the apparatus

for the collection of the water by a short caoutchouc tube. After the operation, the end connected with the latter is broken off by a cut with a file and weighed with the apparatus for collecting the water, and subsequently disconnected, dried, and its weight deducted. His apparatus for collecting the water has also no chloride of calcium in its bulbous part, which enables him to collect the greater part of the water by itself and test its purity. Berzelius also objects to Liebig's method of absorbing the portion of gas remaining in the apparatus, by suction with the mouth, because it does not allow sufficient time to the gases contained in the pores of the remaining oxide to be replaced by the atmospheric air. He also contends that the latter, being derived from the upper proximity of the coal-fire, contains more carbonic acid and vapor than common atmospheric air, which it deposits in the apparatus; while, on the other hand, being deprived of its vapor by passing through the chloride of calcium tube, it absorbs and carries off some water from the potassa apparatus. Berzelius remedies these points by attaching to the open end of the potassa apparatus a short tube containing small fragments of fused caustic potassa. He also performs the suction of atmospheric air very slowly by a small draining apparatus, by which the flow of the water is regulated by a stop-cock, and he connects the broken end of the combustion-tube, where the air enters, with another tube containing pieces of fused caustic potassa, to free the air that enters from its carbonic acid and moisture. Berzelius states that by a comparison of analyses performed after this method, using Liebig's potassa apparatus, and subsequently drawing atmospheric air through the apparatus, with others, by which the carbonic acid was collected over mercury, and no passage in the combustion-tube made for the escape of the gases, but the latter expelled by oxygen generated from a mixture of chlorate of potassa and chloride of sodium introduced at the bottom of the tube, the latter method yields the most accurate results, although it requires a more expensive apparatus.

145. *Liquid volatile substances* are weighed in small glass bulbs, the weights of which are ascertained with accuracy. The liquid is introduced into the bulb by heating them to expel some of the air, and then quickly dipping the open end of their neck into the liquid. On cooling, a portion of the liquid will enter into the bulb to supply the air. The bulb is then again heated gently to expel the remaining air by the vapors of the substance, and once more the end of the neck immersed into the liquid, when it will become nearly filled. The bulbs should be about three-fourths full. They are then sealed and weighed again. By deducting the weight of the empty bulbs from the filled ones, the weight of the contained liquid is obtained. Two bulbs, containing together from 0.4 to 0.5 grammes of the substance, are sufficient. The combustion-tube is first filled with about one to one and a half inch of oxide of copper; one of the bulbs is then introduced into the mouth of the combustion-tube, the sealed end broken off and dropped with the

bulb into the tube. Two or three inches of oxide of copper is then filled on top of it, the other bulb dropped down in the same way, and the rest of the oxide added on top, and the tube immediately adjusted in the furnace. As the usual process of the subsequent desiccation of the oxide of copper in the combustion-tube cannot be employed, additional care ought to be bestowed in preventing the oxide of copper from attracting moisture during its cooling, after previous ignition and its subsequent introduction into the tube. If the substance be very volatile, the parts of the tube containing the two bulbs ought to be protected by additional screens, till the forepart of the tube has become thoroughly ignited, when the screens are removed, and the place where the nearest bulb is situated is slightly heated by an ignited coal. The pointed extremity of the combustion-tube ought also to be surrounded with a few ignited coals to prevent the liquid from condensing in it.

146. *Liquids of less volatility* may be distributed into 3 bulbs; and if their volatility be very inconsiderable, they may be emptied after connecting the combustion-tube with the exhausting-syringe by a single stroke of the latter, causing the air contained in the bulb to expand and expel the liquid. Fixed oils may be weighed in a small and short test-tube, which is slipped down into the combustion-tube after the introduction of 2 inches of oxide of copper; then introducing the rest of the oxide and inclining the combustion-tube, the oil is made to flow out and mix with the oxide. Fatty solid substances may be weighed on small oblong dishes made out of short glass tubes, cracked lengthwise in two, and their extremities bent upward.

147. The combustion of substances containing chlorine must always be performed by chromate of lead, since, by the employment of oxide of copper, they form always some protochloride of copper, which is volatile, and deposits in the chloride of calcium tube, while the chloride of lead does not volatilize. In the combustion of organic substances containing sulphur, some sulphurous acid is apt to be formed, unless the mixture of the substance with the oxide of copper be performed very intimately. When the formation of sulphurous acid is apprehended, a tube containing hyperoxide of lead is interposed between the chloride of calcium tube and the potassa apparatus. The hyperoxide of lead absorbs the sulphurous acid, but does not react with the carbonic acid. The sulphurous acid is not absorbed by the chloride of calcium.

148. *Nitrogenized Substances.* The carbon and hydrogen of nitrogenized substances are determined exactly as described before for non-nitrogenized substances. The presence of nitrogen is indicated by gas-bubbles passing through the potassa apparatus even to the last of the operation. The presence of nitrogen in a substance may be discovered by fusing it in a test-tube with 10 to 15 times its weight of caustic potassa, or with pulverized soda-lime, the preparation of which will presently be given. Nitrogenized substances are hereby decomposed, and all their nitrogen converted

into ammonia, the characteristic odor of which is evolved, and may moreover be made manifest by litmus-paper and other reagents.

149. The quantity of the nitrogen is generally determined by a separate experiment. The nitrogen may be collected as gas, and either the whole quantity given off by the substance measured, or the relative proportion of the carbonic acid and nitrogen gas which it yields, determined; the absolute quantity of the former gas being ascertained by a previous analysis; or the nitrogen may be converted by ignition with alkali into ammonia, and the quantity of this be absorbed by an acid in an apparatus somewhat similar to that used for the absorption of the carbonic acid, and from the quantity of ammonia thus yielded, the quantity of nitrogen calculated. The latter method, which has been contrived but lately, is much the easiest and most accurate, and likely to supersede those formerly used altogether.

150. The difficulties to be contended with in the analysis of nitrogenized substances by oxide of copper, are, avoiding the formation of nitric oxide gas and the presence of a portion of atmospheric air in the apparatus, which always renders its measurement uncertain. In regard to the formation of nitric oxide, Liebig states that the more intimately the mixture with the oxide of copper be made, and the slower the combustion be performed, the less is the danger of its formation. To secure against its formation, the combustion-tube should be made 3 or 4 inches longer than usual, and on top of the oxide a layer of copper turnings be placed, which have been previously oxidized on their surface, by heating in the open air, and then again reduced in a current of hydrogen; or the substance may be mixed for its combustion with oxide of copper that has been already employed once for analysis, and therefore contains a large amount of metallic copper.

151. The examination of the gas obtained by the combustion for the relative proportion of nitrogen and carbonic acid may be performed by an arrangement, as represented in Pl. I., Fig. 9. The substance, which for this purpose need not be weighed, is mixed, as usual, with oxide of copper, and the mixture introduced into the combustion-tube, which it should only half-fill to β . Of the other half of the tube the next fourth is filled with pure oxide of copper to d , and the last fourth with turnings of metallic copper. By placing the screen at m , the metallic copper is first made to ignite, and subsequently the oxide of copper. As soon as they are both at a red heat, another screen, n , is placed about half an inch from the other extremity and this surrounded with ignited charcoal, and the combustion then proceeded with in the ordinary way, beginning, however, from the opposite end of the tube. The gases are collected over mercury in tubes of $\frac{1}{2}$ inch in diameter and 12 to 15 inches long, and divided accurately into volumes. The first portions of gas collected are used in the examination for nitric oxide, by elevating the tube when $\frac{3}{4}$ full, above the level of the mercury, and allowing the mercury in the tube to run out; if any nitrous oxide be present, it produces, by

the admixture of the atmospheric air, red fumes, of which the smallest trace may be observed by looking into the tube from the open end. This test should be repeated several times in the course of the analysis. As soon as the atmospheric air is thoroughly expelled, the gas is preserved in the tubes, of which 6 to 8 are obtained. They are then successively transferred to the tall glass cylinder, Fig. 6, filled with mercury; the height of the mercury outside and inside the tube being brought to the same level, the volume of the gas is read off. A solution of caustic potassa is then introduced into the tube. This is done by aid of the pipette represented by fig. 7. The latter is filled with the potassic solution, its lower extremity, α , closed by mercury and introduced through the mercury in the cylinder, Fig. 6, into the mouth of the tube. Applying the mouth to its upper extremity, β , a sufficient quantity of the potassic solution is forced into the tube. By gentle shaking, the carbonic acid is soon absorbed completely, and the volume of the remaining nitrogen read off, after having restored the mercury outside and inside of the tube to the same level. The rest of the tubes containing the gas are treated in the same way. If the proportion of nitrogen and carbonic acid be found to remain the same during the whole analysis, and no nitric oxide fumes be perceived, the quantity of nitrogen may be computed from this proportion and the known quantity of carbon contained in the substance; equal volumes of carbonic acid and nitrogen corresponding to an equal number of atoms of these elements.

152. If, on the contrary, the proportion of nitrogen and carbonic acid vary at different stages of the analysis, or if the proportion of nitrogen is smaller than $\frac{1}{3}$ of the carbonic acid, it becomes necessary to collect and measure the whole volume of gas given off by a weighed quantity of the substances.

Pl. I., Fig. 4, a , represents the apparatus employed for this purpose. A is a strong glass cylinder filled with mercury, and having three imperfect rings of cork of the shape represented in Fig. 5, X and Y , cemented into it, one at the bottom and the two others at m and n . B is a graduated, narrow, and cylindrical bell-glass, of the capacity of from 200 to 250 cubic centimeters, which moves up and down inside the cork rings. C is a bent glass tube, the inner limb of which reaches above the edge of the cylinder containing the mercury, so as not to be filled by the latter when at its highest level. By placing the graduated bell-glass over the open end of this limb, and depressing it into the mercury till its upper closed top nearly reaches the open end of the limb, most of the air will be expelled through the latter; the other end of the tube is then connected with the combustion-tube containing the mixture of the substance to be analyzed, arranged as in the former case, excepting that the quantity employed for analysis has been accurately weighed. After the connection with the tube C , the tightness of the joints is ascertained by elevating the bell-glass by aid of the stand D , so as to cause the level of the mercury inside to be about an inch higher than outside

if it remain so for some time, the joints are tight. The bell-glass is then again depressed, till the level of the mercury outside and inside is the same, and the volume of gas contained in it read off, and also the temperature and the barometric pressure of the atmosphere observed. The combustion is then performed as in the former case. The gas enters the bell-glass and depresses the mercury, which ought to be kept on the same level with that outside, by gradually raising the bell-glass, in order to avoid any pressure on the inside of the combustion-tube, by which it would be blown out. After the completion of the combustion, the coals are removed and the apparatus allowed to cool, and after the adjustment of the level of the mercury outside and inside, the volume is again determined, with the due correction for a difference in the temperature and barometric pressure, if such have taken place. Having deducted the volume contained in the bell-glass before the combustion, the difference indicates the volume of carbonic acid and nitrogen yielded by the weighed quantity of the substance. The volume of carbonic acid which it yields being calculated from the known quantity of the carbon which it contains, and deducted from the whole mixture of gas, the difference is the nitrogen yielded by it, the weight of which is calculated from its volume.

153. This method has the inconvenience that only small portions of the substance can be employed for the analysis, as the joint volume of the two gases otherwise requires a bell-glass of too great a capacity for their collection. This is avoided by the next method, in which the carbonic acid is absorbed and only the nitrogen left, which may then be measured directly; but both methods have the defect that if the level of the mercury be not kept the same outside and inside the bell-glass during the analysis, by gradually raising the latter, the consequent difference of pressure outside and inside the ignited combustion-tube is apt to alter its bulb and thereby affect the volume of the gas. To avoid this, Liebig prescribes always surrounding the combustion-tube with thin sheet-copper, lined with charcoal dust to prevent adhesion, or, still better, with platinum foil.

154. By the latter method the same apparatus may be employed for the collection of the nitrogen; but at the bottom of the combustion-tube (see Fig. 4, *b*), which should be at least 18 inches long, is first introduced about 2 to 2½ inches of dry hydrate of lime, weighing at least from 4 to 5 grammes, after which one inch of oxide of copper, and then, as usual, the mixture of the oxide with the substance, the rinsings, the pure oxide, and, finally, turnings of metallic copper on top. The combustion-tube is then connected with a tube somewhat resembling the usual chloride of calcium tube, but having an additional bulb *a*, Fig. 4, *b*, which is left empty, the rest of the tube being filled with dry caustic potassa. The apparatus is then adjusted in the furnace and connected with the former apparatus for collecting the gas, A, B, C, D, Fig. 4, *a*. The combustion is performed as in the former case, but from the

front to the back end of the tube. By the passage through the fused caustic potassa, all the carbonic acid and water are absorbed, and nitrogen only left to enter into the bell-glass. At the end of the operation, when the heat reaches the hydrated lime, its water is given off as vapor and expels the carbonic acid yet remaining in the combustion-tube into the potassa apparatus, where it is absorbed. The increase in volume of gas by the combustion is then the whole volume of nitrogen yielded by the quantity of the substance used for analysis, from which its weight is calculated. This method always yields, however, according to Liebig, one per cent. less of nitrogen than it ought, probably from an absorption of the oxygen of the atmospheric air, which is contained in the apparatus from the beginning of the analysis.

155. It will be seen that the estimation of nitrogen by these methods is connected with a great deal of difficulty and uncertainty; it is, therefore, probable that the method lately described by Varrentrapp and Will, which is both easy of execution and, at the same time, more accurate, will entirely supersede all others. It consists in igniting the substance in the usual combustion-tube with a mixture of caustic soda and lime, whereby all the nitrogen is converted into ammonia, which is absorbed in an apparatus (see B, Fig. 10) somewhat similar to Liebig's potassa bulbs, but filled with dilute chlorohydric acid instead of potassa. The quantity of ammonia is then determined by precipitating it with a solution of chloride of platinum, forming an insoluble compound chloroplatinate of ammonium, the quantity of which is determined by weight, and the amount of nitrogen computed from it.

156. *Preparation of caustic Soda-lime.* Caustic soda lye is prepared in the usual way by boiling a solution of carbonate of soda of the proper dilution with freshly slacked lime, straining, clearing, and evaporating the lye; when it becomes concentrated, its strength is ascertained (by a hydrometer), and so much lime added as will form 3 equivalents of lime to 1 equivalent of soda. The mixture is then evaporated to perfect dryness, ignited in a well-covered crucible, pulverized, and kept in well-stoppered bottles. Potassa cannot be employed with equal advantage, on account of its greater fusibility and its hygroscopic properties, and especially on account of the insoluble compound which it forms with chloride of platinum, if any particle of it be carried over by the gases during the ignition.

157. The apparatus employed for the decomposition of the nitrogenized substance is represented in Fig. 10, Pl. I. It consists of an ordinary combustion-tube 16 to 18 inches long, which contains the mixture of the substance with the soda-lime; the one extremity of it is, as usual, drawn out to a point and bent upwards, while the edges of the other and open end are rounded in the fire. By aid of a perforated cork, which need not be desiccated, the tube is to be connected with the apparatus, B, which resembles Liebig's potassa apparatus, but has only one small bulb in the middle, and the extremities of which are not twisted

together, in order to facilitate the subsequent removal of the contained liquid without loss. This apparatus is filled with chlorohydric acid of 1.13 spec. grav. to the height represented in the figure. To have a measure for the quantity of the soda-lime to be mixed with the substance, the combustion-tube is filled about half-full, and this quantity then thoroughly mixed with a weighed quantity of the finely pulverized and desiccated substance, amounting to from 0.2 to 0.4 grammes, according to its greater or smaller content of nitrogen. The mixture should be made very gently, without pressure against the sides of the mortar, to avoid adhesion. It is then introduced into the tube, the mortar and pestle rinsed out several times with small portions of soda-lime, which are added on top of the mixture, and the rest of the tube filled with soda-lime till within an inch of the open end. Will and Varrentrapp prescribe the use of a loose plug of asbestos to prevent particles of the soda-lime being carried over by the gases, which, by the employment of potassa-lime, would spoil the result. The tube is then adjusted in the furnace, and combined with the apparatus containing the chlorohydric acid. To ascertain whether the apparatus be tight, a few air-bubbles should be expelled by a live coal at the inner bulb of the acid apparatus; the acid will then retain some time the higher level in the inner bulb, to which it rises on removing the charcoal. The tube is then ignited gradually in the furnace from one end to the other, care being taken to keep the cork so warm as not to allow any water to condense at it, which would retain some ammonia. By this process, the water contained in the hydrated soda is decomposed, the oxygen combines with the carbon of the substance, while all the nitrogen of the latter combines with the liberated hydrogen to ammonia, which is expelled and absorbed by the chlorohydric acid. At the same time, the hydrogen of the substance is liberated and given off, or it combines with portions of the carbon to carburetted hydrogen, which pass through the acid without being absorbed. During the ignition, no apprehension need be entertained lest the ammonia should not be perfectly absorbed; on the contrary, the ignition must go on so rapidly as to prevent a sudden and violent retrogression of the outer air by the too rapid absorption of the ammonia, by which a portion of the acid might be forced into the combustion-tube. This is so apt to take place with some substances, that it becomes necessary to prevent it by the addition to the mixture of sugar or some other non-nitrogenized substance, in the proportion of about equal weight with that of the substance to be analyzed.

158. When the ignition is completed and the evolution of gas has ceased, the pointed extremity of the ignition-tube should be broken off, and, as usual, a volume of atmospheric air about equal to twice the capacity of the apparatus drawn through it by the suction-tube, by which all remaining ammoniacal vapors are drawn through the acid and absorbed. The apparatus is then disconnected and emptied of its contents into a porcelain capsule, and its inside rinsed first with a mixture of alcohol

and ether, and then with pure water, for which purpose one to one and a half ounces of liquid will suffice. These liquids are added to the original solution, which is mixed with a solution of pure chloride of platinum, evaporated to dryness in a water-bath, and treated with a mixture of two volumes of strong alcohol and one volume of ether. This mixture dissolves the excess of the chloride of platinum, and ought, therefore, to have a yellow color, if a sufficient quantity of the latter has been added, while all the ammonia remains as a combination of chloride of ammonium with chloride of platinum (chloroplatinate of ammonium). The latter is collected on a counterpoised filter, dried, and weighed. As a check, it may be calcined and the weight of the remaining metallic platinum ascertained. From the quantity of the chloroplatinate of ammonium or the metallic platinum, the quantity of nitrogen contained in the substance is calculated; the former containing 6.349 per cent. of nitrogen and the latter corresponding to 14.353 per cent. of the same element. Will and Varrentrapp state that this method is applicable to all nitrogenized substances, except those where the nitrogen exists as nitric acid, or has been added to the substance by oxidation with this acid.

159. Having thus determined the percentage composition of an organic substance, the relative number of atoms is obtained in the usual way (see p. 168). The absolute number of atoms of the different elements, which constitute one atom of the organic substance, or its atomic weight, can only be ascertained by combining it with some other substance, the atomic weight of which is known. This will best be illustrated by an example. Prout found by analysis the percentage composition of urea to be: carbon 19.99, hydrogen 6.65, nitrogen 46.65, oxygen 26.63. If we divide these numbers by the atomic weights of the same, we obtain:

$$\text{Carbon} \dots\dots\dots \frac{19.99}{6.01} = 3.326.$$

$$\text{Hydrogen} \dots\dots\dots \frac{6.65}{1} = 6.65.$$

$$\text{Nitrogen} \dots\dots\dots \frac{46.65}{14.19} = 3.287.$$

$$\text{Oxygen} \dots\dots\dots \frac{26.63}{8.01} = 3.325.$$

$$\text{Now } 3.326 : 6.65 : 3.287 : 3.325 \\ = 1 : 2.0 : 0.992 : 1.0$$

Which last numbers, therefore, represent the relative numbers of the atoms of carbon, hydrogen, nitrogen, and oxygen, in urea, and are very nearly as 1 : 2 : 1 : 1. But to obtain the absolute number of these atoms contained in one atom of urea, or, in other words, to ascertain whether one atom of urea contains one, two, or three, &c., atoms of carbon and a corresponding number of atoms of the other elements, it becomes necessary to combine the urea with another substance, the atomic composition of which is known, and with which it may be considered to form a neutral combination; such a substance is, in this case, oxalic acid. Now, the oxalate of urea, which, there-

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fore, may be considered as containing one atom of urea and one atom of oxalic acid, has been found to consist of:

	In 100 parts.
Urea	57·24
Oxalic acid.....	34·25
Water.....	8·51

But 57·24 urea contains, according to the above analysis, 11·56 carbon, while 34·25 oxalic acid contains 11·45 carbon; one atom of urea and one atom of oxalic acid contain, therefore, the same amount and consequently the same number of atoms of carbon, which, being in oxalic acid, *two* (C_2O_3) must be the same in urea, and one atom of the latter, therefore, contains 2 at. carbon, 4 at. hydrogen, 2 at. nitrogen, and 2 at. oxygen ($C_2H_4N_2O_2$). In order to obtain the atomic weight of urea, we merely have to add together the atomic weights of the above numbers of atoms of its elements; or it may be obtained directly from the composition of the oxalate of urea by the proportion,

$$\begin{array}{rcccl} & \text{Atom. weight} & & \text{At. weight} & \\ & \text{of oxalic acid.} & & \text{of urea.} & \\ \text{as } 34\cdot25 & : & 57\cdot24 & = & 36\cdot05 : x \\ \text{or the atomic weight of urea} & = & 60\cdot24. & & \end{array}$$

160. If, therefore, the substance be an acid, we combine it with a base to a neutral compound, and ascertain the quantity of base with

which it combines; or, if it be a base, we then combine it with an acid and determine the quantity of the latter. Many organic substances, although of a neutral or indifferent nature, combine with oxide of lead, which combinations then afford the means of determining their atomic or combining weight, by estimating the quantity of oxide of lead which these combinations contain. This is generally done by incineration, heating the substance in an open porcelain crucible or capsule with free access of the air, when the organic substance often takes fire and burns away spontaneously. The mixture of metallic lead and oxide of lead which is left, may then be weighed, and the latter dissolved from the former by acetic acid, and its weight ascertained by the loss, and the weight of the remaining metallic lead computed as oxide and added to it. Or the whole mixture of oxide and metallic lead may be dissolved in nitric acid and evaporated to dryness, after the addition of sulphuric acid, and the weight of the sulphate of lead ascertained, from which that of the oxide is computed. When a substance cannot be made to combine with any other substance, its atomic weight, or the number of atoms of its elements which it contains, cannot be determined.

TABLES

FOR CALCULATING THE RESULTS OF CHEMICAL ANALYSIS.

THE following tables are employed to facilitate the calculations of analytical results. The first column contains the name of the substance, the weight of which has been determined by analysis, while the second contains the name of the substance, the corresponding weight of which is to be computed from the former. The third column, headed with 1., shows how much of the substance in the second column corresponds with 1. of that in the first column; and by moving the decimal point to the right or left, we get the corresponding quantity in 10, 100, 1000, &c.; or, 0·1, ·01, ·001, &c. The remaining columns, headed 2., 3., 4., &c., show the quantity of the substance in the second column corresponding to 2, 3, 4, &c. parts of the sub-

stance in the first column; and likewise, whether units, tens, hundreds, &c., or tenths, hundredths, &c., by changing the decimal point. These numbers may be employed for grammes, grains, or any other denomination of weight, while the column headed 1. expresses the percentage of the substance in the second column contained in that in the first column.

A few examples will be sufficient to show the method of employing these tables. Suppose we wish to find how much metallic iron is contained in 2·174 grammes of peroxide of iron. Look in the Table *Iron*, for Peroxide of Iron in the first column with Iron in the second column.

From column, headed 2. write 1·38677 without changing the point.

"	"	"	1.	"	·06934 removing the point 1 place to the left.
"	"	"	7.	"	·04853 removing the point 2 places to the left.
"	"	"	4.	"	·00277 removing the point 3 places to the left.

By addition 1·50741 grammes expresses that 2·174 of peroxide of iron contain 1·50741 of metallic iron.

If sulphur, contained in a substance under analysis, had been converted into sulphuric acid, and then combined with baryta, the Table *Sulphur*, and the line, with Sulphate of Baryta in the first and Sulphur in the second column, will give the quantity of sulphur in the substance, which had been thus converted. Suppose the sulphate of baryta to weigh 25·739 grains. Write the amount for the 2 of the

from the column headed 2., removing the point one place to the right.

From column 2. write 2·7594

"	"	5.	"	·6898
"	"	7.	"	·0966
"	"	3.	"	·0041
"	"	9.	"	·0012

3·5511 grs. of sulphur.

Found.	Required.	1.	2.	3.	4.	5.	6.	7.	8.	9.
I. <i>Aluminium.</i> Al.										
1. Alumina, Al_2O_3	Aluminium, Al_2	0.53295	1.06591	1.59886	2.13181	2.66476	3.19772	3.73067	4.26362	4.79658
2. Alumina, Al_2O_3	Oxygen, O_3	0.46705	0.93409	1.40114	1.86819	2.33524	2.80228	3.26933	3.73638	4.20342
II. <i>Antimony.</i> (Stibium) Sb.										
1. Oxide of Antimony, SbO_3	Antimony, Sb	0.84317	1.68634	2.52951	3.37268	4.21585	5.05902	5.90219	6.74536	7.58853
2. Oxide of Antimony, SbO_3	Oxygen, O_3	0.15683	0.31366	0.47049	0.62732	0.78415	0.94098	1.09781	1.25464	1.41147
3. Antimonious acid, SbO_4	Antimony, Sb	0.80128	1.60257	2.40385	3.20513	4.00641	4.80770	5.60898	6.41026	7.21155
4. Antimonious acid, SbO_4	Oxygen, O_4	0.19872	0.39743	0.59615	0.79487	0.99359	1.19230	1.39102	1.58974	1.78845
5. Antimonic acid, SbO_5	Antimony, Sb	0.76336	1.52672	2.29008	3.05344	3.81680	4.58016	5.34352	6.10688	6.87024
6. Antimonic acid, SbO_5	Oxygen, O_5	0.23664	0.47328	0.70992	0.94656	1.18320	1.41984	1.65648	1.89312	2.12976
7. Sulphuret of Antimony, SbS_3	Antimony, Sb	0.72771	1.45542	2.18313	2.91084	3.63855	4.36626	5.09397	5.82168	6.54939
8. Sulphuret of Antimony, SbS_3	Oxide of Antimony, SbO_3	0.86307	1.72614	2.58921	3.45228	4.31535	5.17842	6.04149	6.90456	7.76763
III. <i>Arsenic.</i> As.										
1. Arsenious acid, AsO_3	Arsenic, As	0.75808	1.51616	2.27424	3.03232	3.79040	4.54849	5.30657	6.06465	6.82273
2. Arsenious acid, AsO_3	Oxygen, O_3	0.24192	0.48384	0.72576	0.96768	1.20960	1.45151	1.69343	1.93535	2.17727
3. Arsenic acid, AsO_5	Arsenic, As	0.65280	1.30560	1.95839	2.61119	3.26399	3.91679	4.56959	5.22238	5.87518
4. Arsenic acid, AsO_5	Oxygen, O_5	0.34720	0.69440	1.04161	1.38881	1.73601	2.08321	2.43041	2.77762	3.12482
5. Sulphuret of Arsenic, AsS_3	Arsenic, As	0.60903	1.21806	1.82709	2.43612	3.04515	3.65418	4.26321	4.87224	5.48127
6. Sulphuret of Arsenic, AsS_3	Arsenious acid, AsO_3	0.80338	1.60676	2.41014	3.21352	4.01690	4.82028	5.62366	6.42704	7.23042
7. Sulphuret of Arsenic, AsS_3	Arsenic, As	0.48311	0.96622	1.44933	1.93244	2.41555	2.89866	3.38177	3.86488	4.34799
8. Sulphuret of Arsenic, AsS_5	Arsenic acid, AsO_5	0.74006	1.48012	2.22018	2.96024	3.70030	4.44036	5.18042	5.92048	6.66054

IV. <i>Barium.</i> Ba.												
1. Baryta,.....	BaO.....	Barium,.....	Ba.....	0.89549	1.79099	2.68648	3.58198	4.47747	5.37296	6.26846	7.16395	8.05945
2. Baryta,.....	BaO.....	Oxygen,.....	O.....	0.10451	0.20901	0.31352	0.41802	0.52253	0.62704	0.73154	0.83605	0.94055
3. Sulphate of Baryta,...	BaO + SO ₃ ...	Baryta,.....	BaO.....	0.65628	1.31256	1.96884	2.62512	3.28140	3.93768	4.59396	5.25024	5.90652
4. Carbonate of Baryta,...	BaO + CO ₂ ...	Baryta,.....	BaO.....	0.77669	1.55338	2.33007	3.10675	3.88344	4.66013	5.43682	6.21351	6.99020
5. Chloride of Barium,..	BaCl.....	Baryta,.....	BaO.....	0.73633	1.47266	2.20899	2.94532	3.68165	4.41798	5.15431	5.89064	6.62697
V. <i>Bismuth.</i> Bi.												
1. Oxide of Bismuth,....	BiO.....	Bismuth,.....	Bi.....	0.89867	1.79735	2.69602	3.59470	4.49337	5.39204	6.29072	7.18939	8.08807
2. Oxide of Bismuth,....	BiO.....	Oxygen,.....	O.....	0.10133	0.20265	0.30398	0.40530	0.50663	0.60796	0.70928	0.81061	0.91193
VI. <i>Boron.</i> B.												
1. Boracic acid,.....	BO ₃	Boron,.....	B.....	0.31190	0.62380	0.93570	1.24760	1.55950	1.87140	2.18330	2.49520	2.80710
2. Boracic acid,.....	BO ₃	Oxygen,.....	O ₃	0.68810	1.37620	2.06430	2.75240	3.44050	4.12860	4.81670	5.50480	6.19290
VII. <i>Bromine.</i> Br.												
1. Bromide of Silver,....	AgBr.....	Bromine,.....	Br.....	0.41989	0.83978	1.25967	1.67956	2.09945	2.51934	2.93923	3.35912	3.77901
2. Bromide of Silver,....	AgBr....	Bromohydric acid,..	HBr.....	0.42524	0.85048	1.27572	1.70096	2.12620	2.55144	2.97668	3.40192	3.82716
VIII. <i>Cadmium.</i> Cd.												
1. Oxide of Cadmium,...	CdO.....	Cadmium,.....	Cd.....	0.87449	1.74899	2.62348	3.49797	4.37246	5.24696	6.12145	6.99594	7.87044
2. Oxide of Cadmium,...	CdO.....	Oxygen.....	O.....	0.12551	0.25101	0.37652	0.50203	0.62754	0.75304	0.87855	1.00406	1.12956
3. Sulphuret of Cadmium,	CdS.....	Oxide of Cadmium,..	CdO.....	0.88734	1.77468	2.66202	3.54936	4.43670	5.32404	6.21138	7.09872	7.98606
IX. <i>Calcium.</i> Ca.												
1. Lime,.....	CaO.....	Calcium,.....	Ca.....	0.71911	1.43823	2.15735	2.87646	3.59558	4.31470	5.03381	5.75293	6.47204
2. Lime,.....	CaO.....	Oxygen,.....	O.....	0.28089	0.56177	0.84265	1.12354	1.40442	1.68530	1.96619	2.24707	2.52796
3. Sulphate of Lime,....	CaO + SO ₃ ...	Lime,.....	CaO.....	0.41532	0.83064	1.24596	1.66128	2.07660	2.49192	2.90724	3.32256	3.73788

Found.	Required.	1.	2.	3.	4.	5.	6.	7.	8.	9.
IX. Calcium. Ca.										
4. Carbonate of Lime, ... $\text{CaO} + \text{CO}_2$...	Lime, CaO	0.56409	1.12818	1.69227	2.25637	2.82046	3.38455	3.94864	4.51273	5.07683
5. Sulphate of Lime, ... $\text{CaO} + \text{SO}_3$...	Carbonate of Lime, $\text{CaO} + \text{CO}_2$	0.73630	1.47260	2.20889	2.94519	3.68149	4.41779	5.15408	5.86038	6.62668
6. Lime, CaO	Carbonic acid, CO_2	0.77276	1.54553	2.31829	3.09106	3.86382	4.63658	5.40935	6.18212	6.95488
7. Carbonic acid, CO_2	Carbonate of Lime, CaO, CO_2	2.29768	4.59537	6.89306	9.19075	11.48844	13.78613	16.08381	18.38150	20.67919
X. Carbon. C.										
1. Oxalic acid, C_2O_3	Oxygen, O_3	0.66631	1.33262	1.99893	2.66524	3.33155	3.99786	4.66418	5.33049	5.99680
2. Carbonic acid, CO_2	Carbon, C	0.27304	0.54609	0.81913	1.09218	1.36522	1.63826	1.91131	2.18435	2.45740
3. Carbonic acid, CO_2	Oxygen, O_2	0.72696	1.45391	2.18087	2.90782	3.63478	4.36174	5.08869	5.81565	6.54260
4. Carbonate of Lime, ... $\text{CaO} + \text{CO}_2$...	Oxalic acid, C_2O_3	0.71336	1.42672	2.14007	2.85343	3.56679	4.28015	4.99351	5.70686	6.42022
5. Carbonate of Lime, ... $\text{CaO} + \text{CO}_2$...	Carbonic acid, CO_2	0.43591	0.87182	1.30773	1.74363	2.17954	2.61545	3.05136	3.48727	3.92317
6. Carbonate of Baryta, $\text{BaO} + \text{CO}_2$.	Carbonic acid, CO_2	0.22331	0.44662	0.66993	0.89325	1.11656	1.33987	1.56318	1.78649	2.00980
XI. Chlorine. Cl.										
1. Chloride of Silver, ... AgCl	Chlorine, Cl	0.24670	0.49340	0.74010	0.98680	1.23350	1.48020	1.72690	1.97360	2.22030
2. Chloride of Silver, ... AgCl	Chlorohydric acid, ... HCl	0.25366	0.50732	0.76098	1.01464	1.26830	1.52196	1.77562	2.02928	2.28294
3. Chlorohydric acid, ... HCl	Chlorine, Cl	0.97258	1.94516	2.91774	3.89032	4.86290	5.83548	6.80806	7.78064	8.75322
XII. Chrome. Cr.										
1. Sesquioxide of Chrome, Cr_2O_3	Oxygen, O_3	0.29891	0.59783	0.89674	1.19565	1.49457	1.79348	2.09239	2.39130	2.69022
2. Chromic acid, CrO_3	Oxygen, O_3	0.46025	0.92050	1.38075	1.84100	2.30126	2.76151	3.22176	3.68201	4.14226
3. Sesquioxide of Chrome, Cr_2O_3	Chromic acid, 2CrO_3 ..	1.29891	2.59782	3.89673	5.19564	6.49455	7.79346	9.09237	10.39128	11.69019
4. Chromate of Baryta, ... $\text{BaO} + \text{CrO}_3$	Chromic acid, CrO_3	0.40518	0.81036	1.21554	1.62072	2.02590	2.43108	2.83626	3.24144	3.64662
5. Chromate of Lead, ... $\text{PbO} + \text{CrO}_3$	Chromic acid, CrO_3	0.31853	0.63706	0.95559	1.27412	1.59265	1.91118	2.22971	2.54824	2.86677

[illegible]

ANALYSIS.

ANALYSIS.

Found.	Required.	1.	2.	3.	4.	5.	6.	7.	8.	9.
XIX. Hydrogen. H.										
1. Water,.....HO	Oxygen,.....O.....	0.8889	1.77778	2.66666	3.55555	4.44444	5.33333	6.22222	7.11110	7.99999
2. Water,.....HO.....	Hydrogen,.....H.....	0.11111	0.22222	0.33334	0.44445	0.55556	0.66667	0.77778	0.88890	1.00001
3. Chlorohydric acid,....HCl.....	Hydrogen,.....H.....	0.02742	0.05484	0.08226	0.10968	0.13710	0.16452	0.19194	0.21936	0.24678
4. Chloride of Ammonium, NH ₄ Cl.....	Ammonia,.....NH ₃	0.32030	0.64060	0.96090	1.28120	1.60150	1.92180	2.24210	2.56240	2.88270
5. Chloroplatinate of Ammonium, ... PtCl ₃ +NH ₄ Cl }	Ammonia,.....NH ₃	0.07632	0.15384	0.23076	0.30768	0.38460	0.46152	0.53844	0.61536	0.69228
6. Platinum.....Pt.....	Ammonia,.....NH ₃	0.17390	0.34780	0.52170	0.69560	0.86950	1.04340	1.21730	1.39120	1.56510
XX. Iodine. I.										
1. Iodide of Silver,.....AgI	Iodine,.....I.....	0.53868	1.07736	1.61604	2.15472	2.69340	3.23208	3.77076	4.30944	4.84812
2. Iodide of Silver,.....AgI	Iodohydric acid, ....HI.....	0.54294	1.08588	1.62882	2.17176	2.71470	3.25764	3.80058	4.34352	4.88646
3. Iodide of Palladium,..Pd	Iodine,.....I.....	0.70344	1.40688	2.11031	2.81375	3.51719	4.22063	4.92406	5.62750	6.33094
XXI. Iridium. Ir.										
1. Chloriridate of Potassium, IrCl ₃ , KCl	Iridium,.....Ir.....	0.40420	0.80840	1.21260	1.61680	2.02100	2.42520	2.82940	3.23360	3.63780
2. Chloririd. of Ammon., IrCl ₃ , NH ₄ Cl.	Iridium,.....Ir.....	0.44232	0.88464	1.32696	1.76928	2.21160	2.65392	3.09624	3.53856	3.98088
XXII. Iron (Ferrum). Fe.										
1. Protoxide of Iron,.....FeO.....	Iron,.....Fe.....	0.77232	1.54464	2.31696	3.08928	3.86160	4.63392	5.40624	6.17856	6.95088
2. Protoxide of Iron,.....FeO.....	Oxygen,.....O.....	0.22768	0.45536	0.68304	0.91072	1.13840	1.36608	1.59376	1.82144	2.04912
3. Peroxide of Iron,.....Fe ₂ O ₃	Iron,.....Fe ₂	0.69338	1.38677	2.08015	2.77354	3.46692	4.16031	4.85369	5.54708	6.24046
4. Peroxide of Iron,.....Fe ₂ O ₃	Oxygen,.....O ₃	0.30662	0.61323	0.91985	1.22646	1.53308	1.83969	2.14631	2.45292	2.75954
5. Peroxide of Iron,.....Fe ₂ O ₃	Protoxide of Iron,....2 FeO....	0.89780	1.79560	2.69340	3.59120	4.48900	5.38680	6.28460	7.18240	8.08020
6. Iron,.....Fe.....	Peroxide of Iron,....Fe ₂ O ₃	1.44220	2.88440	4.32660	5.76880	7.21100	8.65320	10.09540	11.53760	12.97980

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7. Iron,.....Fe.....	Protioxide of Iron,....FeO.....	1.29480	2.58960	3.88440	5.17920	6.47400	7.76880	9.06360	10.35840	11.65320
8. Sulphur,.....S.....	Peroxide of Iron,....FeO ₃ ...	4.86380	9.72760	14.59140	19.45520	24.31900	29.18280	34.04660	38.91040	43.77420
9. Chlorine,.....Cl.....	Peroxide of Iron,....FeO ₃ ...	2.21038	4.42076	6.63114	8.84152	11.05190	13.26228	15.47266	17.68304	19.89342
10. Carbonic acid,.....CO ₂	Protioxide of Iron,....FeO.....	1.59644	3.19287	4.78931	6.38574	7.98218	9.57862	11.17505	12.77149	14.36792
11. Carbonic acid,.....CO ₂	Peroxide of Iron, $\frac{1}{2}$ Fe ₂ O ₃ ..	1.74182	3.48364	5.22546	6.96728	8.70910	10.45093	12.19275	13.93457	15.67639
12. Peroxide of Iron,..... $\frac{1}{2}$ Fe ₂ O ₃	Carbonic acid,.....CO ₂	0.56238	1.12475	1.68713	2.24950	2.81188	3.37426	3.93663	4.49900	5.06138
13. Peroxide of Iron,.....Fe ₂ O ₃	Magnetic oxide of Iron, $\frac{1}{3}$ Fe ₃ O ₄	0.96593	1.93186	2.89778	3.86371	4.82964	5.79557	6.76149	7.72742	8.69335
XXIII. Lead (<i>Plumbum</i>). Pb.										
1. Protioxide of Lead,....PbO.....	Lead,	0.92829	1.85658	2.78487	3.71316	4.64145	5.56974	6.49803	7.42632	8.35461
2. Protioxide of Lead,....PbO.....	Oxygen,.....O.....	0.07171	0.14342	0.21513	0.28684	0.35855	0.43026	0.50197	0.57368	0.64539
3. Chloride of Lead,....PbCl.....	Lead,	0.74519	1.49038	2.23557	2.98076	3.72595	4.47114	5.21633	5.96152	6.70671
4. Chloride of Lead,....PbCl.....	Oxide of Lead,.....PbO.....	0.80275	1.60550	2.40825	3.21100	4.01375	4.81650	5.61925	6.42200	7.22475
5. Sulphate of Lead,....PbO + SO ₃ ...	Lead,	0.68287	1.36574	2.04861	2.73148	3.41435	4.09722	4.78009	5.46296	6.14583
6. Sulphate of Lead,....PbO + SO ₃ ...	Protioxide of Lead, ..PbO.....	0.73563	1.47126	2.20689	2.94252	3.67815	4.41378	5.14941	5.88504	6.62067
7. Sulphuret of Lead, ...PbS.....	Lead,	0.86550	1.73100	2.59650	3.46200	4.32750	5.19300	6.05850	6.92400	7.78950
8. Lead,.....Pb.....	Oxide of Lead,.....PbO.....	1.07725	2.15450	3.23175	4.30900	5.38625	6.46350	7.54075	8.61800	9.69525
XXIV. Lithium. L.										
1. Lithia,.....LO.....	Oxygen	0.55150	1.10300	1.65450	2.20600	2.75750	3.30900	3.86050	4.41200	4.96350
2. Carbonate of Lithia, ..LO + CO ₂ ...	Lithia,	0.39610	0.79220	1.18830	1.58440	1.98050	2.37660	2.77270	3.16880	3.56490
3. Phosphate of Soda and Lithia, ... $\left\{ \begin{array}{l} (2 \text{ NaO} + \text{PO}_5) + (2 \text{ LO} + \text{PO}_5) \end{array} \right\}$	Lithia,	0.12381	0.24762	0.37143	0.49524	0.61905	0.74286	0.86667	0.99048	1.11429
XXV. Magnesium. Mg.										
1. Magnesia,.....MgO.....	Magnesium,.....Mg.....	0.61293	1.22587	1.83880	2.45173	3.06466	3.67760	4.29053	4.90346	5.51640

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Found.	Required.	1.	2.	3.	4.	5.	6.	7.	8.	9.
XXV. Magnesium. Mg.										
2. Magnesia,.....MgO.....	Oxygen,.....O.....	0.38707	0.77413	1.16120	1.54827	1.93534	2.32240	2.70947	3.09654	3.48360
3. Sulphate of Magnesia, MgO + SO ₃ .	Magnesia,.....MgO.....	0.34015	0.68030	1.02045	1.36060	1.70075	2.04090	2.38105	2.72120	3.06135
4. Sulphate of Magnesia, MgO + SO ₃ .	Carbonate of Magn., MgO, CO ₂	0.70238	1.40475	2.10719	2.80951	3.51188	4.21427	4.91664	5.61902	6.32140
5. Phosphate of Magnesia, 2MgO + PO ₅ .	Magnesia,.....2 MgO ..	0.36671	0.73342	1.10013	1.46684	1.83355	2.20026	2.56697	2.93368	3.30039
6. Phosphate of Magnesia, 2MgO + PO ₅ .	Carbonat. of Mag., 2(MgO, CO ₂)	0.37862	0.75724	1.13585	1.51447	1.89309	2.27171	2.64033	3.02895	3.40756
7. Magnesia,.....MgO.....	Carbonic acid,.....CO ₂	1.06491	2.12982	3.19473	4.25964	5.32456	6.38947	7.45438	8.51929	9.58420
8. Carbonic acid,.....CO ₂	Carbonate of Magn., MgO, CO ₂	1.93912	3.87823	5.81735	7.75647	9.69558	11.63470	13.57382	15.51294	17.45205
XXVI. Manganese. Mn.										
1. Protoxide of Manganese, MnO.....	Oxygen,.....O.....	0.22427	0.44853	0.67280	0.89706	1.12133	1.34560	1.56986	1.79413	2.01839
2. Sesquioxide of Manganese, Mn ₂ O ₃ ..	Oxygen,.....O ₃	0.30248	0.60496	0.90744	1.20992	1.51240	1.81488	2.11736	2.41984	2.72232
3. Binoxide of Manganese, MnO ₂	Oxygen,.....O ₂	0.36637	0.73274	1.09911	1.46548	1.83185	2.19822	2.56459	2.93096	3.29733
4. Manganoso-Manganic oxide, Mn ₃ O ₄ .	Protoxide of Manganese, 3MnO	0.93044	1.86088	2.79132	3.72176	4.65220	5.58264	6.51308	7.44352	8.37396
5. Manganoso-Manganic oxide, Mn ₃ O ₄ .	Sesquioxide of Mang., 1½Mn ₂ O ₃	1.03478	2.06956	3.10424	4.13912	5.17390	6.20868	7.24346	8.27824	9.31302
6. Manganoso-Manganic oxide, Mn ₃ O ₄ .	Binoxide of Mang.,..3 MnO ₂ .	1.13911	2.27822	3.41733	4.55644	5.69555	6.83466	7.97377	9.11288	10.25199
7. Protosulphate of Mang., MnO + SO ₃	Protoxide of Manganese, MnO	0.47082	0.94164	1.41246	1.88328	2.35410	2.82492	3.29574	3.76656	4.23738
8. Protoxide of Manganese, MnO.....	Carbonic acid,.....CO ₂	0.61253	1.22505	1.83758	2.45011	3.06264	3.67517	4.28769	4.90022	5.51275
XXVII. Mercury (Hydrargyrum). Hg.										
1. Suboxide of Mercury, Hg ₂ O.....	Oxygen,.....O.....	0.03800	0.07600	0.11400	0.15200	0.19000	0.22799	0.26599	0.30399	0.34199
2. Oxide of Mercury,....HgO.....	Mercury,.....Hg.....	0.92678	1.85357	2.78035	3.70714	4.63392	5.56070	6.48749	7.41427	8.34106
3. Oxide of Mercury,....HgO.....	Oxygen,.....O.....	0.07322	0.14643	0.21965	0.29286	0.36608	0.43930	0.51251	0.58573	0.65894

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4. Subchloride of Mercury, Hg_2Cl_2	Mercury,.....	Hg.....	0.85117	1.70234	2.55351	3.40468	4.25585	5.10702	5.95819	6.80936	7.66053
5. Subchloride of Mercury, Hg_2Cl_2	Suboxide of Mercury, Hg_2O ...		0.88480	1.76960	2.65440	3.53920	4.42400	5.30880	6.19360	7.07840	7.96320
6. Chloride of Mercury, HgCl_2	Mercury,.....	Hg.....	0.74091	1.48182	2.22273	2.96364	3.70455	4.44546	5.18637	5.92728	6.66819
7. Chloride of Mercury, HgCl_2	Oxide of Mercury, HgO		0.79944	1.59888	2.39832	3.19776	3.99720	4.79664	5.59608	6.39552	7.19496
8. Sulphuret of Mercury, HgS	Oxide of Mercury, HgO		0.93104	1.86208	2.79312	3.72416	4.65520	5.58624	6.51728	7.44832	8.37936
9. Sulphuret of Mercury, HgS	Chloride of Mercury, HgCl ...		1.16461	2.32922	3.49383	4.65844	5.82305	6.98766	8.15227	9.31688	10.48149
10. Mercury,.....	Oxide of Mercury, HgO		1.07900	2.15800	3.23700	4.31600	5.39500	6.47400	7.55300	8.63200	9.71100
XXVIII. <i>Molybdenum</i> . Mo.											
1. Protoxide of Molybdenum, MoO	Oxygen,.....	O.....	0.14316	0.28632	0.42948	0.57264	0.71580	0.85895	1.00211	1.14527	1.28843
2. Binoxide of Molybdenum, MoO_2	Oxygen,.....	O_2	0.25046	0.50092	0.75139	1.00185	1.25231	1.50277	1.75323	2.00370	2.25416
3. Molybdic acid,.....	Oxygen,.....	O_3	0.33388	0.66776	1.00164	1.33552	1.66941	2.00329	2.33717	2.67105	3.00493
4. Bisulphuret of Molybdenum, MoS_2 ...	Molybdenum,.....	Mo.....	0.59802	1.19604	1.79406	2.39208	2.99010	3.58812	4.18614	4.78416	5.38218
XXIX. <i>Nickel</i> . Ni.											
1. Oxide of Nickel,.....	NiO.....	Ni.....	0.78709	1.57417	2.36126	3.14835	3.93543	4.72252	5.50961	6.29670	7.08378
2. Oxide of Nickel,.....	NiO.....	O.....	0.21291	0.42583	0.63874	0.85165	1.06457	1.27748	1.49039	1.70330	1.91622
XXX. <i>Nitrogen</i> . N.											
1. Chloroplatinate of Ammonium, $\text{NH}_4\text{Cl} + \text{PtCl}_2$...	Nitrogen,.....	N.....	0.06349	0.12698	0.19047	0.25396	0.31746	0.38095	0.44444	0.50793	0.57142
2. Platinum,.....	Nitrogen,.....	N.....	0.14353	0.28705	0.42058	0.57410	0.71763	0.86116	1.00468	1.14821	1.29173
3. Nitric acid,.....	Nitrous acid,.....	NO_3	0.70459	1.40918	2.11377	2.81836	3.52295	4.22754	4.93213	5.63672	6.34131
4. Sulphate of Baryta, $\text{BaO} + \text{SO}_3$...	Nitric acid,.....	NO_5	0.46434	0.92868	1.39302	1.85736	2.32170	2.78604	3.25038	3.71472	4.17906
5. Cyanide of Silver,.....	Cyanogen,.....	NC_2	0.19620	0.39240	0.58860	0.78480	0.98100	1.17720	1.37340	1.56960	1.76580
6. Cyanide of Silver,.....	Cyanohydric acid, NC_2H ...		0.20362	0.40724	0.61086	0.81448	1.01810	1.22172	1.42534	1.62896	1.83258

Found.	Required.	1.	2.	3.	4.	5.	6.	7.	8.	9.
XXXI. Osmium. Os.										
1. Sulphuret of Osmium, $\text{OsS} \dots \dots \dots \left\{ \begin{array}{l} \text{KCl} + \text{PdCl} \end{array} \right\}$	Osmium, $\dots \dots \dots \text{Os} \dots \dots \dots$	51	1.02	1.53	2.04	2.55	3.06	3.57	4.08	4.59
XXXII. Palladium. Pd.										
1. Chloropalladite of Potassium, $\dots \dots \dots \left\{ \begin{array}{l} \text{KCl} + \text{PdCl} \end{array} \right\}$	Palladium, $\dots \dots \dots \text{Pd} \dots \dots \dots$	0.32622	0.65244	0.97866	1.30488	1.63110	1.95732	2.28354	2.60976	2.93598
XXXIII. Phosphorus. P.										
1. Phosphoric acid, $\dots \dots \text{PO}_5 \dots \dots \dots$	Phosphorus, $\dots \dots \dots \text{P} \dots \dots \dots$	0.43966	0.87931	1.31897	1.75863	2.19828	2.63794	3.07760	3.51726	3.95691
2. Phosphoric acid, $\dots \dots \text{PO}_5 \dots \dots \dots$	Oxygen, $\dots \dots \dots \text{O}_5 \dots \dots \dots$	0.56034	1.12069	1.68103	2.24137	2.80172	3.36206	3.92240	4.48274	5.04309
3. Phosphate of Baryta, $2 \text{BaO} + \text{PO}_5 \dots \dots \dots$	Phosphoric acid, $\dots \dots \text{PO}_5 \dots \dots \dots$	0.31799	0.63598	0.95397	1.27196	1.58995	1.90794	2.22593	2.54392	2.86191
4. Phosphate of Lime, $\dots 2 \text{CaO} + \text{PO}_5 \dots \dots \dots$	Phosphoric acid, $\dots \dots \text{PO}_5 \dots \dots \dots$	0.55618	1.11236	1.66854	2.22472	2.78090	3.33708	3.89326	4.44944	5.00562
5. Phosphate of Lead, $\dots 2 \text{PbO} + \text{PO}_5 \dots \dots \dots$	Phosphoric acid, $\dots \dots \text{PO}_5 \dots \dots \dots$	0.24239	0.48478	0.72717	0.96956	1.21195	1.45434	1.69673	1.93912	2.18151
XXXIV. Platinum. Pt.										
1. Chloroplatinate of Potassium, $\dots \dots \dots \left\{ \begin{array}{l} \text{KCl} + \text{PtCl}_2 \end{array} \right\}$	Platinum, $\dots \dots \dots \text{Pt} \dots \dots \dots$	0.40420	0.80840	1.21260	1.61680	2.02100	2.42520	2.82940	3.23360	3.63780
2. Chloroplatinate of Ammonium, $\dots \dots \dots \left\{ \begin{array}{l} \text{NH}_4\text{Cl} + \text{PtCl}_2 \end{array} \right\}$	Platinum, $\dots \dots \dots \text{Pt} \dots \dots \dots$	0.44232	0.88464	1.32696	1.76928	2.21160	2.65392	3.09624	3.53856	3.98088
XXXV. Potassium (Kaliu). K.										
1. Potassa, $\dots \dots \dots \text{KO} \dots \dots \dots$	Potassium, $\dots \dots \dots \text{K} \dots \dots \dots$	0.83048	1.66097	2.49145	3.32194	4.15242	4.98290	5.81339	6.64387	7.47436
2. Potassa, $\dots \dots \dots \text{KO} \dots \dots \dots$	Oxygen, $\dots \dots \dots \text{O} \dots \dots \dots$	0.16952	0.33903	0.50855	0.67806	0.84758	1.01710	1.18661	1.35613	1.52564
3. Sulphate of Potassa, $\dots \text{KO} + \text{SO}_3 \dots \dots \dots$	Potassa, $\dots \dots \dots \text{KO} \dots \dots \dots$	0.54067	1.08134	1.62201	2.16268	2.70335	3.24402	3.78469	4.32536	4.86603
4. Chloride of Potassium, $\text{KCl} \dots \dots \dots$	Potassa, $\dots \dots \dots \text{KO} \dots \dots \dots$	0.63257	1.26514	1.89771	2.53028	3.16285	3.79542	4.42799	5.06056	5.69313
5. Carbonate of Potassa, $\text{KO} + \text{CO}_2 \dots \dots \dots$	Potassa, $\dots \dots \dots \text{KO} \dots \dots \dots$	0.68196	1.36391	2.04587	2.72783	3.40978	4.09174	4.77370	5.45565	6.13761
6. Chloroplatinate of Potassium, $\dots \dots \dots \left\{ \begin{array}{l} \text{KCl} + \text{PtCl}_2 \end{array} \right\}$	Potassa, $\dots \dots \dots \text{KO} \dots \dots \dots$	0.19334	0.38668	0.58002	0.77336	0.96670	1.16004	1.35338	1.54672	1.74006

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7. Chloroplatinate of Potassium,.... KCl + PtCl ₂ }	0-30565	0-61130	0-91695	1-22260	1-52825	1-83390	2-13955	2-44520	2-75085
8. Platinum, .....Pt	0-47834	0-95668	1-43502	1-91336	2-39170	2-87004	3-34838	3-82672	4-30506
XXXVI. <i>Selenium. Se.</i>									
1. Selenate of Baryta, ...BaO + SeO ₃ .	0-45367	0-90734	1-36101	1-81468	2-26835	2-72202	3-17569	3-62936	4-08303
2. Selenate of Baryta, ...BaO + SeO ₃ .	0-39657	0-79314	1-18971	1-58628	1-98285	2-37942	2-77599	3-17256	3-56913
XXXVII. <i>Silicon. Si</i>									
1. Silicic acid (Silica), ...SiO ₃	0-51950	1-03900	1-55850	2-07800	2-59750	3-11700	3-63650	4-15600	4-67500
XXXVIII. <i>Silver (Argentum). Ag.</i>									
1. Oxide of Silver, .....AgO	0-93111	1-86222	2-79333	3-72444	4-65555	5-58667	6-51778	7-44889	8-38000
2. Oxide of Silver, .....AgO	0-06889	0-13778	0-20667	0-27556	0-34445	0-41333	0-48222	0-55111	0-62000
3. Chloride of Silver, ...AgCl	0-80903	1-61806	2-42709	3-23612	4-04515	4-85418	5-66321	6-47224	7-28127
4. Chloride of Silver, ...AgCl	0-75330	1-50660	2-25990	3-01320	3-76650	4-51980	5-27310	6-02640	6-77970
5. Sulphuret of Silver, ...AgS	0-87045	1-74090	2-61135	3-48180	4-35225	5-22270	6-09315	6-96360	7-83405
6. Sulphuret of Silver, ...AgS	0-93485	1-86970	2-80455	3-73940	4-67425	5-60910	6-54395	7-47880	8-41365
XXXIX. <i>Sodium (Natrium). Na.</i>									
1. Soda, .....NaO	0-74418	1-48836	2-23253	2-97671	3-72089	4-46507	5-20925	5-95342	6-69760
2. Soda, .....NaO	0-25582	0-51164	0-76747	1-02329	1-27911	1-53493	1-79075	2-04658	2-30240
3. Sulphate of Soda, ...NaO + SO ₃ ..	0-43819	0-87638	1-31457	1-75276	2-19095	2-62914	3-06733	3-50552	3-94371
4. Carbonate of Soda, ...NaO + CO ₂ ..	0-58692	1-17384	1-76076	2-34768	2-93459	3-52151	4-10843	4-69535	5-28227
5. Chloride of Sodium, ...NaCl	0-53289	1-06578	1-59867	2-13156	2-66445	3-19734	3-73023	4-26312	4-79601
XL. <i>Strontium. Sr.</i>									
1. Strontia,SrO	0-84551	1-69102	2-53653	3-38204	4-22755	5-07306	5-91857	6-76408	7-60959

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Found.	Required.	1.	2.	3.	4.	5.	6.	7.	8.	9.
XL. Strontium. Sr.										
2. Strontia,	Oxygen,	0.15449	0.30898	0.46347	0.61796	0.77245	0.92694	1.08143	1.23592	1.39041
3. Sulphate of Strontia, ..	Strontia,	0.56360	1.12720	1.69080	2.25440	2.81800	3.38160	3.94520	4.50880	5.07240
4. Carbonate of Strontia, SrO + CO ₂ ..	Strontia,	0.70174	1.40347	2.10521	2.80695	3.50869	4.21043	4.91216	5.61390	6.31564
5. Chloride of Strontium, SrCl	Strontia,	0.65387	1.30774	1.96161	2.61548	3.26935	3.92322	4.57709	5.23096	5.88483
XLI. Sulphur. S.										
1. Sulphate of Baryta, ...BaO + SO ₃ ..	Sulphur,	0.13797	0.27594	0.41391	0.55188	0.68985	0.82782	0.96579	1.10376	1.24173
2. Sulphate of Baryta, ...BaO + SO ₃ ..	Sulphurous acid, ...SO ₂	0.27514	0.55028	0.82542	1.10056	1.37570	1.65084	1.92598	2.20112	2.47626
3. Sulphate of Baryta, ...BaO + SO ₃ ..	Sulphuric acid, ...SO ₃	0.34372	0.68744	1.03116	1.37488	1.71860	2.06232	2.40604	2.74976	3.09348
4. Sulphate of Lime, ...CaO + SO ₃ ..	Sulphuric acid, ...SO ₃	0.58468	1.16936	1.75404	2.33872	2.92340	3.50808	4.09276	4.67744	5.26212
5. Sulphate of Lead, ...PbO + SO ₃ ..	Sulphur,	0.10612	0.21224	0.31836	0.42448	0.53060	0.63672	0.74284	0.84896	0.95508
6. Sulphate of Lead, ...PbO + SO ₃ ..	Sulphuric acid, ...SO ₃	0.26437	0.52874	0.79311	1.05748	1.32185	1.58622	1.85059	2.11496	2.37933
7. Sulphuret of Silver, ...AgS.....	Hyposulphurous acid, S ₂ O ₂ ...	0.38791	0.77582	1.16373	1.55164	1.93955	2.32746	2.71537	3.10328	3.49119
8. Sulphuret of Silver, ...AgS.....	Sulphur,	0.12955	0.25910	0.38865	0.51820	0.64775	0.77730	0.90685	1.03640	1.16595
9. Sulphuretted Hydrogen, HS.....	Sulphur,	0.94159	1.88318	2.82477	3.76636	4.70795	5.64954	6.59113	7.53272	8.47431
XLII. Tellurium. Te.										
1. Tellurous acid, .....TeO ₂	Oxygen,	0.19958	0.39916	0.59874	0.79832	0.99790	1.19748	1.39706	1.59664	1.79622
2. Telluric acid, .....TeO ₃	Oxygen,	0.27220	0.54440	0.81660	1.08880	1.36100	1.63320	1.90540	2.17760	2.44980
3. Sulphuret of Tellurium, TeS	Tellurium,	0.66596	1.33192	1.99788	2.66384	3.32980	3.99576	4.66172	5.32768	5.99364
4. Sulphuret of Tellurium, TeS.....	Tellurous acid, .....TeO ₂	0.83201	1.66402	2.49603	3.32804	4.16005	4.99206	5.82407	6.65608	7.48809

Found.	Required.	1.	2.	3.	4.	5.	6.	7.	8.	9.
XLVIII. Zinc. Zn.										
1. Oxide of Zinc,.....ZnO.....	Zinc,.....Zn.....	0.80128	1.60256	2.40385	3.20513	4.00641	4.80769	5.60897	6.41026	7.21154
2. Oxide of Zinc,.....ZnO.....	Oxygen,.....O.....	0.19872	0.39744	0.59615	0.79487	0.99359	1.19231	1.39103	1.58974	1.78846
3. Sulphate of Zinc,.....ZnO + SO ₃ ...	Oxide of Zinc,.....ZnO.....	0.50103	1.00206	1.50309	2.00412	2.50515	3.00618	3.50721	4.00824	4.50927
4. Oxide of Zinc,.....ZnO.....	Sulphuret of Zinc,.,ZnS....	1.20120	2.4024	3.60361	4.80481	6.00601	7.20721	8.40841	9.60962	10.81082
XLIX. Zirconium. Zr.										
1. Zirconia,.....ZrO ₃	Oxygen,.....O ₃	0.26305	0.52610	0.78914	1.05219	1.31524	1.57829	1.84135	2.10440	2.36745

☞ In consequence of the late researches on Uranium, Cerium, and Yttrium, and the discovery of other metals associated with the two last, they are necessarily excluded from the Tables.

ANATASE. *Min.* (αντασις, elongation, from the height of the octahedra). *Syn.* Octahedrite (from its occurrence in Octahedra), Oisanite (from its locality Oisans), Pyramidal Titanium-ore, Titane Anatase.

Descrip. Small crystals of tetragonal system, adjacent sides of radical 8-hedron = $97^{\circ} 38'$, opposite sides = $137^{\circ} 10'$; combin. the 1st obtuser 8-hedron on the edges of the radical, with a sharper and a flatter of same order, 2 flatter 8-hedra of same order with the radical, a dioctahedron, terminal plane, and vertical square prism on edges of radical; radical on term. plane = $111^{\circ} 25'$. Cleavage perfect parallel to radical and terminal plane.

H. = 5.5–6. G. = 3.857, *Häuy*; 3.826, *Mohs*.

Color blue, passing into brown, red, and black, greenish yellow by transmitted light; lustre of fragments splendid, submetallic; translucent, opaque; brittle; grayish white streak. By heat it phosphoresces reddish yellow for a moment.

Behavior. Like pure titanic acid, infusible before the blowpipe; dissolves in borax to a colorless glass, becoming in the inner flame yellow and amethystine; difficultly soluble in mic. salt, the bead generally becoming blue in the reducing flame. Acids do not attack it; rendered soluble by ignition with a mixture of 2 pts. carbonate of soda and 2 pts. carbonate of potassa. (See *Titanic acid* under TITANIUM.)

Analysis has shown it to be pure titanic acid, but it has not been latterly examined.

Localities chiefly at Oisans Dauphiné, associated with felspar, epidote, axinite, chrichtonite, &c. in granite and mica-slate; in the latter rock in the Grisons; at Tavatsch in Tyrol; in clay-slate, Norway; in granite in Cornwall and Spain; in detached crystals and nodules, and in quartz, at Itabira, Brazil.

ANAXITE. *Min.* (αναξις, without increase). Found in the neighborhood of Bilin in veins of disintegrated volcanic rock, and resembles Pyrophyllite. Greenish-white, translucent on the edges, composed of fine grains,

with lamellar structure. G. = 2.265. Gives water in the matrass, burns white before the blowpipe, its edges becoming slightly rounded, splits off without swelling, unlike pyrophyllite (hence its name). With the fluxes and cobalt-solution it shows its content of iron, silica and alumina. An incomplete analysis by Plattner gave 55.7 silica, 11.5 water, much alumina, some magnesia, and protoxide of iron. *Berz.* and *Ram.*

ANCHUSIC ACID, ANCHUSINE. *Chem.* See ALKANET.

ANDALUSITE. *Min.* *Syn.* Chiastolite, Macle, Crucite. Felspath apyre, *Häuy*.

Descrip. Cryst. right-rhombic prism of $91^{\circ} 33'$ and $88^{\circ} 27'$, the edges levelled by another vertical 4-sided prism, the adjacent sides of which = $128^{\circ} 6'$, or with the main prism = $161^{\circ} 43'$; the larger terminal plane with small planes of a horizontal prism = $144^{\circ} 44'$. Cleavage parallel to the main rhombic prism. Occurs also subcolumnar and granular.

H. = 7.5. G. = 3.13–3.32.

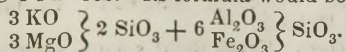
Color gray or reddish; lustre vitreous; sub-translucent-opaque; streak white; tough, with uneven fracture; streak white. Chiastolite is now associated with andalusite, although they appeared to differ from the impurities associated with the former; hence its hardness varying from 3 to 7.5, and the variations in analyses. The crystals of chiastolite generally appear to consist of four individuals, arranged in a right or oblique cruciform manner.

Behavior. Infusible alone, dissolves with difficulty in borax to a clear glass; decomposed with greater difficulty by mic. salt; with soda swells without fusion; with cobalt-solution gives a blue. Not attacked by acids.

Analysis. Of Andalusite, 1. from Spain by Vauquelin; 2. from Herzogau in Oberpfalz by Bucholz; and from the Linsenz Alp, Tyrol, 3. by Brandes, 4. by Bunsen, and 5. by Thomson; of Chiastolite from Lancashire, Massachusetts, 6. by C. T. Jackson, 7. by Bunsen.

	1.	2.	3.	4.	5.	6.	7.
Silica	38	36.5	34.000	40.17	35.304	33.0	39.09
Alumina	52	60.5	55.750	58.62	60.196	61.0	58.56
Peroxide of Iron ..	2	4.0	3.375	—	(FeO 1.324	4.0)	—
Ox. of Manganese .	—	—	0.625	0.51	—	—	0.53
Magnesia	—	—	0.375	—	1.000	—	—
Lime	—	—	2.125	0.28	—	—	0.21
Potassa	8	—	2.000	—	—	—	—
Water	—	—	1.000	—	2.032	1.5	Vol. mat. 0.99
	100	101.0	99.250	99.58	99.856	99.5	99.38

The analyses of Bunsen are probably more to be relied on for purity of material, and, according to them it is a $\frac{2}{3}$ basic silicate of alumina. Formula, $4 \text{Al}_2\text{O}_3, 3 \text{SiO}_2$, which, by calculation, gives $\text{SiO}_2 = 40.27 + \text{Al}_2\text{O}_3 59.73 = 100$. According to Berzelius, some larger and soft crystals of chiastolite are a variety of talc, as shown by an analysis of the same from Bretagne by Arfvedson who found $\text{SiO}_2 46.3 + \text{Al}_2\text{O}_3 36.0 + \text{Fe}_2\text{O}_3 2.6 + \text{MgO } 2.7 + \text{KO } 11.3 + \text{HO } 1.1 = 100$. Its formula would be



Localities. In primary rocks. First found in Andalusia, Spain. In the Linsenz Alp, Tyrol, in large crystals; Braunsdorf, Saxony; Landeck, Silesia; Guldenstein, Moravia; Bavaria; Herzogau, Pfalz; Forez, France; Elba; Bottriffney, Banffshire; Killeny, Ireland. In the United States at Westford, Mass., abundant; Litchfield Conn., rare; Chester, Del. Co., Pa.; Chiastolite at Jago di Compostella, Spain; Barèges, Pyrenees; Cumberland, England; in the United States, Lancashire and Sterling, Mass.; Bellows Falls, Vt. *Ram.*

ANEMONIN. *Chem.* A neutral principle

ANGELICA.

apparently a camphor or stearopten, found in *Anemone Pulsatilla*, *memorosa* and *pratense*.

Prep. Pour over the bruised and fresh plant twice its weight of water, distil off the half, redistil $\frac{1}{2}$ of the distillate and set it in a cool place; the anemonin crystallizes out in a few weeks.

Prop. White scales or needles, of an extremely pungent odor and taste, heavier than water; very soluble in ether, slightly in water; heated it fuses and volatilizes with an extremely pungent acrid odor, violently attacking the eyes and nose, but it cannot be distilled unchanged. Long ebullition with nitric acid decomposes it, but chlorine, iodine, and bromine scarcely attack it; soluble in cold sulphuric acid, from which water precipitates it, but the solution is decomposed by heat; concentrated chlorohydric acid converts it into *anemonic acid*. Form., $C_7H_3O_4$. Löwig. Fehling found A. very soluble in hot alcohol, difficultly in ether and water; the alcoholic solution always left a white, pulverulent substance, insoluble in those three menstrua, as well as in the fixed and volatile oils. His 4 analyses give $C_5H_2O_2$. By boiling it with oxide of lead and water, he obtained a crystalline compound of the formula, $C_{15}H_6O_6$, PbO .

Anemonic acid (Ger. Anemoninsäure) is obtained, according to Löwig, by boiling anemonin with barytic water, removing the excess of baryta by carbonic acid, precipitating the filtered solution with acetate of lead, decomposing the yellow anemionate of lead by sulphuretted hydrogen, and evaporating the filtered solution of anemonic acid to dryness. It is a brown, translucent, brittle, amorphous mass, easily rubbed to a yellow powder; deliquescent, very soluble in water, not in ether, with difficulty in alcohol; tastes and reacts acid, decomposing carbonates; decomposed by distillation; its salts are amorphous. Form., $C_4H_4O_3$, HO. Löwig. Schwarz's anemic acid (Anemonsäure) requires confirmation.

ANGELICA. Bot. The root of this plant (*Archangelica*, *angelica*), growing abundantly in Northern Europe; has at first a sweet taste, then hot, aromatic, bitter. The analyses of the root are by John, and by Bucholz and Brandes.

	John.	Buch. & Br.
Vol. oil, sharp taste, trace	.....	0.70
Resin....Do.	6.7	6.02
Bitter extract....	12.5	Extractive 26.40
Gum	33.5	(with salt) 31.75
Starch (Inulin), .	4.0	(not Inulin) ... 5.40
Soluble in potassa	7.3	Extr. deposit... 0.66
Woody fibre	30.0	 8.60
Water	} 6.0	 17.50
Loss		 2.00
		Albumen 0.97

100

100

B. and B. term the acrid, soft resin *Angelica-balsam*, on which, with the oil, the active properties of the seeds and root depend. To prepare it, extract the dry root with alcohol, and add water, which dissolves the extractive. The balsam is blackish brown, soluble in sulphuric acid with brownish red color, in potassa-

ANHYDRITE.

lye by heat, in alcohol, ether, spt. terpentine, and almond oil, with a yellow color.

ANGLARITE. Min. See VIVIANITE.

ANGLESITE. Min. See LEAD-VITRIOL.

ANGOSTURA. Bot. Syn. *Angustura*. The bark of *Galipea officinalis* and *Cusparia* (the latter *Bonplandia trifoliata*), from the forests of tropical America. It should not be confounded with the bark of the *Nux-Vomica* tree, sometimes termed False *Angustura*. Fischer's analysis of the true Ang. bark gives:

Volatile oil.....	0.3
Bitter hard resin	1.7
Balsamic resin.....	1.9
Elastic resin	0.2
Bitter extract.....	3.7
Gum.....	5.7
Lignin.....	89.1

102.6

Pfaff's analysis gave beside the above, free tartaric acid, tartrate, sulphate and muriate of potassa, and sulphate of lime. Saladin discovered in it a peculiar principle (the bitter extract) which he termed *Cusparin*.

The volatile oil is obtained by distilling the bark with water. It is yellowish white, lighter than water, peculiar odor, acrid taste. The hard resin is brown, bitter, soluble in alcohol, acetic ether, and potassa; insoluble in common ether and oil of terpentine. The soft resin is greenish yellow, acrid, soluble in alcohol, ether, oil of terpentine, and almonds; insoluble in potassa; colored red by nitric acid.

Cusparin. Syn. *Angosturin*. This principle, the bitter extract, is prepared, according to Saladin, by extracting 1 pt. bark by 3 pts. absolute alcohol, and evaporating spontaneously at 16° Fahr.; the crystalline aggregations are separated from the liquid, pressed, rinsed with a little water, treated with ether, dissolved in alcohol of 0.833, shaken with freshly precipitated oxide of lead, the greater part of the alcohol distilled off, and the residue exposed to 18°—20°. Concentric groups of crystals are formed. *Cusparin* forms irregular tetrahedra, fuses at a gentle heat, losing 23.09 per cent. of its weight, with higher heat inflames, without giving an odor of nitrogenous matter, and without a residue; 1000 water at 59° dissolve 5.45, at 212° 11.04; 100 alcohol of 0.8536 dissolve 37 at 53.6°; insoluble in ether and vol. oils; soluble in alkali. Chlorine changes it into a peculiar acid; iodine, bromine, nitric and sulphuric acids change its color. Its aqueous solution is not precipitated by neutral salts of both oxides of iron, nor neutral or basic acetate of lead; while infusion of galls produces a caseous precipitate.

Use. In Pharmacy. A powerful aromatic or stimulant tonic, its stimulant properties being due to the oil and resin, its tonic to the bitter principle.

ANHYDRITE. Min. (name signifies *without water*). Syn. *Cubespars* (Ger. *Wurfelspath*), *Muriacite*, *Vulpinite*, *Karstenite*, *Prismatic Gypsum Haloide*.

Description. Cryst. Right square prismatic. Combinations are the prism with terminal

ANHYDROUS.

plane, and sometimes a 2d prism replacing the edges of the 1st, the angles of the two adjoining prisms = $129^{\circ} 56'$ and $140^{\circ} 4'$; cleaves parallel to main prism, less perfectly parallel to terminal plane. Structure also lamellar and fibrous, often contorted, granular, and sometimes impalpable.

H. = 3—3.5. G. = 2.9—2.957

(2.96 in vacuo at 39°).

Color white, grayish, bluish, or reddish, brick-red; lustre pearly on the prism, vitreous on terminal plane, and rather vitreous in the lamellar and fibrous; transparent, translucent; has double refraction.

Behavior. Yields no water, or only a trace,

	1.
Sulphuric acid.....	59.78
Lime	43.06
Sesquioxide of Iron	0.10
Silica	0.25
Water	—
Carbonic acid.....	—
Bitumen.....	—
	103.19

Formula, CaO, SO_3 , or anhydrous sulphate of lime.

Localities. Well crystallized at salt-mines of Bex, Switzerland; and at Hall and Bochnia, Tyrol; at Aussee, crystallized and massive, the latter brick-red; at Sulz on the Neckar; Bleiberg, Carinthia; Himmelsberg near Ilfeld; Berehtesgaden, Bavaria; salt mines of Wieliczka, Poland; Vulpino near Bergamo, Italy, where its unusual hardness renders it useful for cutting into ornaments. In the United States at Lockport, New York, of fine blue, usually lamellar and transparent.

ANHYDROUS. *Chem.* From *av*, without *Aug*, water. A term frequently applied to substances destitute of water. The metallic oxides are usually precipitated as hydrates, i.e. chemically combined with water, which they lose by heat, becoming anhydrous or dry oxides. Alcohol and other organic bodies have a strong attraction for water, although they may not combine with it in definite proportion, and when freed from it they are also termed anhydrous. Anhydrous alcohol is also termed absolute alcohol.

ANHYDROUS SILICATE OF IRON. *Min.* H = 4. G = 3.884. Foliated masses, cleaving readily into 4-sided prisms, dark, brown, opaque, brittle, magnetic. Heated in a closed tube loses about 2 per cent. of volatile matter, including ammoniacal vapor; infusible alone, but in reducing flame assumes metallic lustre; soluble in chlorohydric acid, leaving silica in flakes. An analysis by Thompson gives silica $29.60 +$ protoxide of iron $68.73 +$ protox. of manganese $1.78 = 100.11$. Form., $3\text{FeO}, \text{SiO}_3$, or $\frac{1}{3}$ protosilicate of iron. Locality at Slavcarrach, Mourne mountains, Northern Ireland. See **CHLOROPHÆITE**, **FAYALITE**, and *Silicates of Iron*.

ANIL or **NIL**, **ANILIN**, **ANILIC ACID**. See **INDIGO**.

ANIMAL CHARCOAL. *Tech.* The residue from the dry distillation of various parts of

ANIMAL CHEMISTRY.

in a matrass; fuses with difficulty on charcoal to a white enamel, and by strong fire is reduced to sulphuret, either alone or mixed with soda. Forms, with borax, a clear glass, becoming yellow or brownish on cooling, according to the quantity in the bead. Fuses into a clear bead with fluor-spar, becoming an opaque white enamel on cooling, and by continued heating swells without fusion. Very slightly soluble in water and acids,

Analysis. 1. Of a blue variety from Sulz on the Neckar; 2. of the fibrous from Ilfeld; 3. of the coarse; and, 4. of the fine granular from Vulpino; 1 by Klaproth, 2, 3, and 4 by Stro-meyer:

	2.	3.	4.
	55.801	56.7765	58.0075
	40.673	41.4056	41.7042
	.254	.0324	—
	.231	.2596	.0900
	2.914	.9428	.0725
	.087	—	—
	.040	—	—
	100	99.4169	99.8742

animals, bones, blood, flesh, scrapings of hides, and leather, clippings of hoofs and horns, woollen and silk rags, &c. They are distilled either for their volatile matters as a chief product, or for the residuary coal, which is employed either in the manufacture of prussiate of potassa, or for decolorizing and purifying solutions of sugar, spirits, and other liquids. For the volatile products see Manufacture of Sal-ammoniac under **AMMONIUM**. For the uses of the charcoal, see *Ferrocyanide of Potassium* under **CYANOGEN**; and for the last purpose, **BONE-BLACK**.

ANIMAL CHEMISTRY. Organic bodies are distinguished from inorganic by always consisting of 2 or more of a few elements, carbon, hydrogen, oxygen, and nitrogen, with a few others; by consisting usually of a large number of equivalents and by consequently being complex in their composition; by their ready decomposition or separation into simpler forms of matter. Many of them have also a compound radical, as basis, composed of 2 or 3 elements, carbon and hydrogen, or these with nitrogen, which act as elements combining oxygen, sulphur, &c., and their oxides with acids. We may distinguish between organic and organized bodies; the latter, while in connection with the plant or animal, partaking of its vitality and consequently not being obedient to the decomposing laws of affinity, but rather employing these forces to elaborate materials from the organic matters around them in order to reproduce themselves. The fibrin and albumen of the blood are of this character. Organic bodies are produced by the joint action of those organized, such as sugar, gum, oily matters, vegetable acids, alkaloids, &c.

The organic and organized matters produced by plants constitute the food of animals, which employ them partly for nutrition and partly for combustion. The important organized constituents of the animal system are all nitrogenous; and hence the necessity of nitrogenous

ANIME.

food to supply their gradual waste and decay. Starch, gum, sugar, oils, &c., containing no nitrogen, support life but for a short time, their principal use being to supply carbon for combustion, wherewith the heat of the body is maintained.

In *respiration* the amylaceous and oily substances, &c. are burned, their oxygen uniting with as much of their hydrogen as is necessary to form water, while their carbon and the excess of hydrogen are converted into carbonic acid and water. The dark venous blood absorbs oxygen from the air in the lungs becoming of a florid red, and arterialized; but the greater part of the oxidation takes place in the extreme capillaries, from which the venous blood conveys carbonic acid to the lungs, where it parts with it, takes up oxygen, and becomes again arterialized. This oxidation appears to be sufficient to account for animal heat, and hence we may view the animal frame as an apparatus of combustion, in which the organized and organic substances generated by plants are burned and converted into simpler forms of matter, carbonic acid, water, &c.

To supply this combustion and the waste of the animal body, the organic materials of food enter into the system by simple absorption, animals merely assimilating without organizing them. It has been shown by the analyses of Mulder and others that fibrin, albumen, and casein have the same composition, whether obtained from vegetables or animals, whence Liebig draws the conclusion that animals do not organize them, but draw them ready formed from plants, the herbivorous receiving them directly, carnivorous animals indirectly.

The minutæ of the operations of respiration, digestion, and the various animal functions are still subjects of speculation and research, nor is it desirable in a practical work to enter on this field until it shall have been more fully explored. Dumas, Bous-singault, and others maintain that the fatty matters are not organized by the animal, but received ready formed from plants; while Liebig holds that they are due to the metamorphosis of amylaceous and other portions of food within the animal frame.

Certain it is that a path of research has been opened by the surprising discoveries in Organic Chemistry, which bids fair to unfold many of the hitherto concealed operations in the complex system of animals, which were formerly referred to the indefinite action of vitality, and promises a clearer view of the cause and state of disease, with a more certain application of remedies on sound chemical principles. For farther details, refer to *RESPIRATION* and *DIGESTION*; to the substances, *ALBUMEN*, *CASEIN*, *FIBRIN*, *GLUTEN*, *LEGUMIN*, and *PROTEIN*; and farther, to the articles *BILE*, *BLOOD*, *CHYLE*, *FAT*, *URINE*, &c.

ANIME. Tech. A resin, of which there are two varieties, the American and the Oriental. The *American Anime* is said to flow from incisions in the *Hymenæa Courbaril*, a tree growing in Brazil and the West Indies. The purer resin occurs in pale-yellow pieces, with a vitreous fracture and dusty surface; softens in the mouth, tastes like mastic, and has an

ANISE.

agreeable odor, especially when heated; spec. grav. 1.03; combustible with a lively flame. Warm oil of olives or lavender dissolve it; it is wholly soluble in boiling alcohol, the solution reddening litmus, although the acid is scarcely extracted by water. Cold alcohol separates it into two resins, the soluble (54.3 per cent.) resembles the resin itself; the difficultly soluble resin (42.8 per cent.) precipitates from a boiling alcoholic solution, drying to a tasteless mass, slightly odorous and lighter than water. It also contains about 2.4 per cent. of a volatile oil, which passes off by heating alone or with water. A brown variety does not soften in the mouth.

The *Oriental anime* has a spec. grav. 1.0272, appears to be a mixture of 2 resins, one pale-yellow, brittle, not softening in the mouth, the other reddish yellow, softer; it does not contain the difficultly soluble resin, and its alcoholic solution has a less acid reaction. It is not decomposed by nitric acid, even at the heat of fusion.

Anise was formerly employed in Pharmacy, but is now chiefly used for scenting pastilles, &c.

ANISE. Tech. Phar. The seed of *Pimpinella Anisum* (or *Anisum sativum*), a native of Scio and Egypt, extensively cultivated in Germany, Spain, &c. The following are the analytic results of Brandes and Reimann:

Volatile oil.....	3.00
Resin.....	0.58
Cryst. fat and chlorophyll. . .	0.12
Fat oil.....	3.38
Phytocol? (extractive, &c.)...	7.85
Uncryst. sugar.....	0.65
Gum.....	6.50
Extractive.....	0.50
Anise-Ulmin?.....	8.60
Gummoin.....	2.90
Salts of lime and potassa....	8.17
Inorganic salts, &c.....	3.55
Lignin.....	32.85
Water.....	23.00

101.65

The fat oil was of a buttery consistence, soluble in alcohol, leaving a resin; saponifiable by potassa, leaving a white substance, not examined. Neither the anise-ulmine nor the gummoin can be regarded as simple bodies. The salts of lime and potassa are malates and bimalates, acetates, phosphates, and sulphates, the inorganic include silicic acid and oxide of iron.

Oil of anise is prepared by distilling the seed with water, about 2 per cent. being the yield. It is transparent and colorless, or slightly yellow, with the aromatic odor and taste of the seed; spec. grav. 0.979 fresh, increasing to 0.985 when old; congeals at 50° and liquefies at 62°; these points varying with the variable proportion of elaeopten and stearopten. It is miscible in all proportions with alcohol of 0.806, soluble at 77° in 2.4 pts. alcohol of 8.4. It slowly oxidizes in the air, becoming thicker, resinous, and loses the property of depositing its stearopten. With fuming nitric acid, it

ANISE.

forms an orange-colored, soft resin and oxalic (or benzoic) acid. It consists of elaeopten and stearopten, the latter often $\frac{1}{3}$ of the oil. The former has not been studied.

Anise-Stearopten or *Camphor*. The solid constituent of the oil or the stearopten, is proved by Cahours to be identical with the stearoptens of Fennel and Star-anise. It is prepared from anise-oil, in which it exists in greater quantity, $\frac{4}{5}$ of the whole, by pressing the oil at 32° between bibulous paper until it ceases to absorb oil, when the solid is crystallized several times from alcohol of 0.85 to obtain it pure.

Prop. White, shining laminæ, about as heavy as water, with a feebler and more agreeable odor than the crude oil, is brittle, especially at 32° ; fuses at about 64° , boils at 432° , volatilizing almost unchanged at this temperature, but becoming yellow. The solid stearopten is not altered by long contact with oxygen or air, but when kept fluid it gradually loses its crystallizability. The analyses of Blanchet and Sell, Dumas, and lately of Cahours, prove that its composition is either $C_{10}H_6O$, or $C_{20}H_{12}O_2$; the latter being deduced by Cahours from its combination with chlorohydric acid; it is therefore isomeric with cuminole or hydruret of cumyl.

Anise-stearopten, treated with dry bromine, and purified by solution from ether, forms large, shining, colorless, inodorous crystals, insoluble in water, somewhat soluble in alcohol, more so in ether, decomposing above 212° . Form., $C_{20}H_9$, Br_3O_2 , 3 eq. hydrogen being replaced by 3 of bromine. Chlorine displaces hydrogen in a similar manner, but it seems in proportion to the quantity of chlorine. The former is termed by Cahours *Bromanisal*.

Anisoin. One pt. stearopten rubbed with $1\frac{1}{2}$ oil of vitriol is changed into a resinous mass, from which the greater part of the acid can be extracted by boiling with water. The resin is then distilled, part passing over as a solid, but the greater part decomposed into a volatile aromatic oil. The solid is white, inodorous, fuses above 212° , insoluble in water, slightly soluble in alcohol, more so in ether, from which it crystallizes. Form., $C_{20}H_{12}O_2$, being isomeric with the stearopten. The same substance is formed by strong phosphoric acid, and by the dry chlorides of tin and antimony.

Anisic acid. Prepared by boiling anise-stearopten with nitric acid of 1.2, washing the separated crystals with cold water, and subliming them; colorless, shining needles, slightly soluble in cold, readily in hot water, very soluble in alcohol and ether, forms crystallizable salts with alkalis, crystalline precipitates with the oxides of lead and silver. Formula of the crystallized acid, $C_{16}H_6O_5 + HO$, the water being replaced in salts by a metallic oxide.

Anisole is formed by the distillation of anisic acid from an excess of baryta or lime. It is a very mobile, colorless, aromatic liquid, boiling above 302° , insoluble in water, soluble in alcohol and ether; it forms, with bromine, chlorine, and nitric acid, crystallized products. Anisole is formed by the abstraction of 2 eq. carbonic acid from cryst. anisic acid; thus, $C_{16}H_7O_6 - 2 CO_2 = C_{14}H_7O_2$.

Nitranisic acid. The stearopten boiled with strong nitric acid of 1.33 is first resolved into

ANORTHITE.

an oily body, but when, by continued action, it is dissolved, the solution is diluted, and the nitranisic acid separates in yellow flocculæ. It is washed, combined with ammonia, crystallized several times, and precipitated by nitric acid to render it pure. It is soluble in boiling water, more in alcohol; its alkaline salts are readily soluble, its alkalino-earthly difficultly. Form. of the cryst. acid $= C_{16}H_5NO_9 + HO$, of the dry acid $= C_{16}H_5O_4 + NO_5$. Another substance obtained by the action of fuming nitric is termed *Nitranisid*.

ANKERITE. *Min.* See MAGNESITE.

ANNEALING. *Tech.* Syn. Nealing, Tempering. *Lat.* Recoquere. *Fr.* Recuire, Recuit. *Ger.* Anlassen. *Saxon.* Anhelan. Many substances, after undergoing the rapid processes of the manufacturer, become more or less brittle, and consequently, less adapted to the employment for which they are designed; and in order to restore the desired toughness they are subjected to the operation of annealing or tempering. Glass vessels were almost useless unless annealed. Thus, melted glass dropped into water forms Prince Rupert's drops or tears, the small end of which being broken off, the whole drop bursts into powder with an explosive force and noise. A vial or thin tumbler, suffered to cool in the air (called the Bologna-vial), will often bear the stroke of a leaden bullet or other blunt and soft body suffered to fall into it without fracture, but if a flint or sharp piece of sand be dropped into it, the vessel will violently fly to pieces. This liability to fracture is greatly lessened by placing the vessels as soon as made in the annealing furnace, where they are slowly cooled for some hours or even days, according to the thickness of the glass. Several metals becoming more or less brittle by hammering and rolling, receive their wonted toughness by heating to redness. Brittle cast iron may be made softer and tougher by maintaining it for some time at a full red heat and cooling it slowly. The process of tempering steel depends on the same principles. It is heated and suddenly plunged into a cold liquid, which hardens it and renders it more or less brittle; by heating this hardened metal to different temperatures, its hardness is diminished in proportion to the temperature, a process termed tempering.

The particles of glass or metal in the brittle state are supposed to be in a state of high cohesive tension, and by the operation of reheating are restored to a state better adapted to the exertion of cohesive force.

ANORTHITE. *Min.* Syn. Anorthotomous Felspar, Christianite, Biotin.

Descrip. Cryst. Doubly oblique rhombic system, with a perfect cleavage parallel to main plane, P, and lateral plane, M. It occurs also columnar.

H. = 6. G. = 2.65—2.78.

Color white; lustre vitreous, pearly on cleavage-planes; transparent, translucent; fracture conchoidal. Resembles felspar.

Behavior. It behaves like felspar before the blowpipe, but yields with soda only a white enamel. Soluble in chlorohydric acid, the silica not gelatinizing.

ANNATTO.

ANTHRACITE.

Analysis. 1. From Monte Somma by G. Rose, and 2. by Abich; 3. from Java by Reinwardt:

	1.	2.	3.
Silica	44.49	44.98	46
Alumina	34.46	33.84	37
Lime	15.68	18.07	14.5
Magnesia	5.26	1.56	—
Perox. of Iron...	0.74	0.33	—
Potassa.....	—	0.88	—
Soda	—	trace	0.6
	100.63	99.66	98.1

Rose subsequently found 2 per cent. potassa.

Localities. Old lavas of Monte Somma, in chloritic masses with ice-spar, augite, mica, idocrase; on the island Procida near Naples; Java.

ANNATTO. See ARNOTTO.

ANTHOPHYLLITE. *Min.* See HORN-
BLENDE.

ANTHRACEN. *Chem.* See *Paranaphthalin* under NAPHTHALIN.

ANTHRACITE. *Geol.* A coal formation, containing little or no bituminous matter, and sometimes as high as 95 per cent. carbon. The largest formation is composed in the several basins in central Pennsylvania, east of the Susquehanna river; other formations are in England and France, beside smaller deposits of the same geological age; and a few localities where basalt intruded through the brown coal, appears to have deprived it of its bitumen, and converted it into a species of anthracite. The following analyses will exhibit the chemical character of this coal:

<i>Pennsylvania Anthracite.</i>	Spec. grav.	Carbon.	Vol. matter.	Ashes.
Nesquehoning mines, Northampton county	—	86.60	6.40	7.00
Summit mines, Lehigh Company	—	88.50	7.50	4.00
Tamaqua mines, Schuylkill co.	1.57	92.07	5.03	2.90
Schenoweth vein, Pottsville	1.50	94.10	1.40	4.50
Sharp Mountain, Pinegrove	1.54	79.57	7.15	3.28
Black Spring Gap, Dauphin co.	1.44	82.47	9.53	8.00
Lykens Valley, Dauphin co.	—	88.25	8.85	2.90
Wilkesbarre, Luzerne co.	1.403	88.90	7.68	3.49
Carbondale, Luzerne co.	1.404	90.23	7.07	2.70
<i>Foreign Anthracite.</i>				
Durham, England	—	82.0	13.0	5.0
Wales	—	88.0	8.6	3.4
Mons, France	—	85.0	12.7	2.3
Rolduc	1.34	87.0	10.3	2.7
Fresne	1.36	86.3	9.4	4.3
Lamure	1.608	91.3	6.0	2.7
Baconnière	—	66.5	8.5	25.0

The following analyses by Jacquelin (*An. de Ch. de Ph.* lxxiv. 200) show the ultimate composition of some foreign anthracites. 1. from

Coalbrook, Caermarthenshire, 2. from Sablé Sarthe, 3. from Vizille, Isère, 4. from Isère, 5. from Pembrokeshire, analyzed by Schafhäütl.

	1.	2.	3.	4.	5.
Carbon	90.58	87.22	94.09	94.00	94.100
Hydrogen	3.60	2.49	1.85	1.49	2.390
Nitrogen	0.29	2.31	2.85	0.58	0.874
Oxygen	3.81	1.08	—	—	1.336
Ashes	1.72	6.90	1.90	4.00	1.300

The volatile matter in the purer varieties is almost exclusively water; but in the same basin in Pennsylvania may be traced a gradual transition from those burning without flame to those containing a sufficient quantity of bitumen to burn more freely and with flame. This fact has been clearly shown in the most southern basin, where numerous analyses made along the whole line from Pottsville, in a southwesterly direction towards the Susquehanna, show the gradual increase of volatile matter from 2—5 per cent. to 12—16 per cent., so that the latter coals towards the S. W. termination of the basin approximate to bituminous coals. The ashes of anthracite necessarily varies in composition, consisting of a silicate of alumina, with variable quantities of oxide of iron, magnesia, lime, &c., the two last being often absent. Sulphur (in sulphuret of iron, pyrites) is also a variable constituent, from $\frac{1}{2}$ to 1 per cent., being usually much less than the proportion in

bituminous coals. From our own experiments the existence of nitrogen is shown from the ammoniacal salt, which can be detected in the fine ashes frequently found in the flues leading from anthracite stoves. Moreover, where the flues are of sheet-iron and not porous earthenware, some 50 per cent. of this ash is chloride of ammonium (sal-ammoniac); the presence of chlorine would hence indicate the marine character of the coal.

Uses. Anthracite has been employed in Philadelphia for heating apartments since 1820; and within 10 years successfully for culinary operations, both in close stoves and open grates. The advantages it possesses for these purposes are the long-continuance and uniform combustion of the fire, the little attention it requires, freedom from smoke, its greater cleanliness, and the little liability to communicate fire from sparks, &c. Its disadvantages are the intensity and very drying character of

ANTHRACONITE.

the heat, although the latter difficulty may be obviated by the use of open vessels of water, with stoves and hot-air furnaces.

The same advantages render it very superior as a fuel for numerous technical processes. After many unsuccessful attempts made in Pennsylvania to employ it in the reduction of iron from its ores, Mr. Crane fully succeeded at his iron-works in Wales, England, in 1837, by the use of the hot-blast, since which it has been employed with variable success in the United States. For some technical operations it is less valuable, such as in the manufacture of glass, in some reverberatories, where the transported heat of flame appears to be better adapted to the purposes required. Notwithstanding the great number of practical applications which anthracite has received, we have yet to witness its far more varied and general employment both in domestic economy and in manufactures.

ANTHRACONITE. *Min.* See **CALCAREOUS SPAR.**

ANTHRANILIC ACID. *Chem.* See **INDIGO.**

ANTHOSIDERITE. *Min.* (*ανθος, flower, σιδος, iron*). *Description* by Hausmann. Fine fibrous, radiated, flower-like. $H = 6.5$. $G =$ about 3.0. Color grayish, ochre-brown; lustre feeble silky, somewhat opalescent; translucent in very thin laminae; very rough. Apparently not dissolved by borax and mic. salt, even in powder, but the bead has an iron color.

Analysis by Wöhler:

	Experiment.	Equivs.	Calcul.
Silica.....	60.08	3	61.36
Peroxide of Iron..	34.99	1	34.66
Water.....	3.59	1	3.98
	98.66		100

Formula, $Fe_2O_3, 3 SiO_3 + HO$. Wöhler believes that the same mineral occurs in those hydrated oxides, which leave a portion of gelatinous silica after dissolving the oxide of iron by treatment with muriatic acid. The mineral, accompanied by magnetic iron, was from Antonio Pereiro, Minas Geraes in Brazil. *Berz. Jahresb.* xxii. 194.

ANTIARIN. *Phar.* The active principle in the celebrated Upas-poison, derived from the *Antiaris toxicaria*, a tree growing in Java, Sumatra, and Borneo to the height of 60 to 100 ft. The poison is prepared by making incisions into the tree and inspissating the milky juice, with other materials, to a thick fluid of a fawn color and unpleasant odor. Although a violent poison, the former narrations of its dreadful character are entirely fabulous.

Mulder's late analyses of the pure gum-resin give the following results:

Vegetable albumen	16.14
Gum	12.34
Sugar	6.31
Resin	20.93
Myricin	7.02
Antiarin	3.56
Extractive matter.....	33.70
	100.00

Antiarin. Colorless, crystalline scales, solu-

ANTIMONIAL ORES.

ble at 72.5° in 251 water, in 70 alcohol, and 2792 ether; soluble in 27.4 boiling water; more soluble in acid and alkaline than in pure water; neutral. It does not combine with ammoniacal nor muriatic acid gas. Its formula deduced from analysis and its chemically combined water is $C_{14}H_{10}O_5$, and the crystals have 2 eq. water.

The resin is acid, and its alcoholic solution precipitated with acetate of lead, gave 23.44 oxide of lead + 76.56 resin = 100. This antiar-resinate contains 3 times as much oxygen as the oxide of lead, so that the equiv. of the resin is 3 times as great as in the formula, or the salt is a triresinate. Formula = $C_{16}H_{12}O$.

The *myricin* resembles myricin of bees or myrtle wax in every respect except in composition, in which it differs slightly. Formula, $C_{10}H_9O$.

ANTIGORITE. *Min. Descrip.* Occurs like talc in slaty masses of a blackish green color, and may be split into translucent flakes, thin laminae of which are transparent; lustre glimmering. $H = 2.5$. $G = 2.622$.

Behavior. Yields water in the matrass; fuses in very thin laminae on the edges to a yellowish brown slag; ignited in a crucible becomes silver-white, with feeble metallic lustre; dissolves in borax and mic. salt, giving an iron color; the bead with mic. salt becomes milky on cooling. Soluble with difficulty in chlorohydric acid, the silica separating in flocculae; more readily decomposed by sulphuric acid.

Analysis by Schweizer.

Silica	46.22	46.18
Protoxide of Iron....	13.05	12.68
Magnesia	34.39	35.19
Alumina	2.08	1.89
Water	3.70	3.70
	99.44	99.64

Probable formula, $\frac{3 MgO}{3 FeO} \left\{ 2 SiO_3 + MgO, HO \right\}$, which allies it to serpentine. It occurs in Antigorio valley, near Domo d' Ossola in Piemont. Schweizer in *Berz. Jahresb.* xxi. 175.

ANTIMONIAL ORES. The following list comprises nearly all known ores of antimony with their formula:

1. Native Antimony... = Sb.
2. Antimonial Nickel..... Ni_2Sb .
3. Antimonial Silver..... Ag_4Sb and Ag_6Sb .
4. Sulphantimonial
Nickel..... $NiS_2 + NiSb(As)$.
5. Oxide of Antimony. SbO_3 .
6. Antimonious acid.. SbO_4 .
7. Romëin
8. Antimonic acid... SbO_5 .
9. Gray Antimony.... SbS_3 .
10. Red Antimony.... $SbO_3 + 2 SbS_3$.
11. Zinkenite
12. Miargyrite..... AgS, SbS_3 .
13. Berthierite (see 18) $FeS + SbS_3$.
14. Antimonial Copper (see this).
15. Cupreous Antimony $Cu_2S + SbS_3$.
16. Plagionite
17. Jamesonite
18. Berthierite (see 13) $2 (FeS, SbS_3) + PbS$.
19. Feather ore

ANTIMONIAL.

20. Boulangerite.. $\text{PbS, SbS}_3 + 2 \text{ PbS}$.
21. Ruby Silver } $\text{AgS, SbS}_3 + 2 \text{ AgS}$.
(dark)..... }
22. Bournonite.... $(\text{Cu}_2\text{S, SbS}_3 + 2 \text{ Cu}_2\text{S}) +$
 $2 (\text{PbS, SbS}_3 + 2 \text{ PbS})$.
23. Gray Copper.. (see this).
24. Geokronite.... $\text{PbS, SbS}_3 + 4 \text{ PbS}$.
25. Kilbrickenite.. $\text{PbS, SbS}_3 + 5 \text{ PbS}$.
26. Brittle Silver.. $\text{AgS, SbS}_3 + 5 \text{ AgS}$.
27. Polybasite.... $\text{AgS } \left\{ \begin{array}{l} \text{SbS}_3 \\ \text{Cu}_2\text{S} \end{array} \right\} + 8 \left\{ \begin{array}{l} \text{AgS} \\ \text{Cu}_2\text{S} \end{array} \right\}$
28. Kobellite $\text{BiS } \left\{ \begin{array}{l} \text{SbS}_3 \\ \text{BiS} \end{array} \right\} + 10 \left\{ \begin{array}{l} \text{PbS} \\ \text{BiS} \end{array} \right\} +$
 (3 FeS) .

ANTIMONIAL COPPER. *Min.* *Ger.* Antimonkupferglanz. Fuses on charcoal with intumescence to a lead-gray metallic globule, which, by continued calcination with soda, gives a globule of copper; the charcoal is coated yellow and white. Fuses in a closed tube to a reddish brown slag, with the sublimation of sulphur and sulphuret of arsenic. The antimonial copper from St. Gertraud in the Levant-thale, Carinthia, yielded in Schrötter's analysis,

Lead.....	29.902
Copper.....	17.352
Antimony.....	16.647
Arsenic.....	6.036
Iron.....	1.404
Sulphur.....	23.602

This result will not permit the establishment of a formula, for calculating the metals as, $\text{PbS, CuS, FeS}_2, \text{SbS}_3, \text{AsS}_3$, the quantity of sulphur taken up would be only 25.229 instead of 28.602. *Rammelsberg.*

ANTIMONIAL NICKEL. *Min.* *Syn.* Antimoniuret or Antimoniet of Nickel. *Descrip.* Thin hexagonal plates. $\text{H} =$ about 5.5. Color on fresh surfaces light copper-red with violet tint; lustre metallic, splendent; opaque; streak reddish-brown; fracture uneven, small subconchoidal; brittle; not magnetic.

Behavior. Some antimony sublimes in a closed tube; it gives a heavy coating of antimony on charcoal; difficultly fusible in minute pieces. Difficultly soluble in acids, readily and fully in aqua regia.

Two analyses by Stromeyer, give—

Nickel.....	28.946	27.054
Antimony.....	63.734	59.706
Iron.....	0.866	0.842
Galena.....	6.437	12.557
	99.983	99.959

Calculated in its pure state, free from galena, its formula is Ni_2Sb .

ANTIMONIAL SILVER. *Min.* *Syn.* Antimoniuret or Antimoniet of Silver, Prismatic or Octahedral Antimony. *Ger.* Spiessglassilber. *Fr.* Argent Antimonial.

Descrip. Cryst. probably right rhombic, with distinct cleavage parallel to a horizontal prism; combinations similar to arragonite; faces deeply striated longitudinally. It generally occurs massive and loose granular.

$\text{H} = 3.5. \text{G} = 9.44 - 9.82.$

Color silver-white, often externally tarnished

ANTIMONY.

yellow, gray, or black; lustre metallic; opaque; somewhat brittle; fracture uneven.

Behavior. Fuses on charcoal to a gray, brittle globule, fuming like antimony, but less; calcined to a certain point it congeals crystalline; by a longer heat it leaves pure silver; charcoal is coated by white antimony, sometimes reddish; it yields white oxide in the open tube, and the residue is surrounded by a dark yellow glass. Soluble in nitric acid, leaving oxide of antimony.

Analysis. 1. Coarse grained; 2. fine grained from Wolfach; 3. lamellar granular from Andreasberg, by Klaproth; and, 4. by Vauquelin.

	1.	2.	3.	4.
Silver.....	76	84	77	78
Antimony.....	24	16	23	22

If the analyses are all correct, 1, 3, and 4 have a formula, Ag_4Sb , and 2 is nearly Ag_6Sb .

Local. Wolfach in Baden, Andreasberg on the Harz, Guadalcanal in Spain, Allemont in France.

ANTIMONIC ACID. *Min.* It appears to occur native; it becomes dark-yellow by heat, and loses oxygen.

ANTIMONIOUS ACID. *Min.* Yields water in a closed tube; not reduced alone on charcoal, but gives a slight coating; easily reduced with soda.

Formula, $\text{SbO}_3 + m \text{ HO}$.

ANTIMONIATES. *Chem.* Salts of antimonious acid. See **ANTIMONY**.

ANTIMONITES. *Chem.* Salts of antimonious acid. See **ANTIMONY**.

ANTIMONY. *Chem.* *Syn.* *Gr.* στίμιον or στίβις. *Lat.* Stibium, Antimonium. *Ger.* Spiessglanz, Spiessglas. *Fr.* Antimoine.

Symb. *Sb.*—*Equiv.* 129.24 (or, $\text{O} = 100$, 1612.90).—Berzelius terms this equiv. 2 atoms; one atom therefore = 64.62 (or 806.45).

History. The sulphuret was known in the most ancient times under the names above given and others, such as *πλατυφθαλμον*, *having large eyes*, from its use by females as a pigment for the eyes. The metal and many of its compounds were the results of the researches of alchemists, and were described by Basil Valentine about 1490. Antimony is rather an abundant metal, occurring chiefly as sulphuret (see **GRAY ANTIMONY**), the quantity of ore imported into England at present averaging 650 tons annually. It is employed as a metal to impart hardness to other metals, in its compounds in pharmacy and a few technical operations.

NON-SALINE COMPOUNDS OF ANTIMONY.

	Formula.	$\text{H} = 1$	$\text{O} = 100$
Antimony.....	Sb	129.2	1612.9
Alloys.....	—	—	—
Oxide of Antimony...	SbO_3	153.2	1912.9
Antimonious acid....	SbO_3	161.3	2012.9
Antimonic acid.....	SbO_5	169.3	2112.9
Sulphuret of A.	SbS_3	177.5	2216.4
Oxysulphuret of A. ...	$\text{SbO}_3 \left\{ \begin{array}{l} 2 \\ \text{SbS}_3 \end{array} \right\}$	508.2	6345.7
Sulphantimonious acid	SbO_4	193.7	2417.56
Sulphantimonic acid..	SbO_6	209.8	2618.73
Phosphuret of A.	—	—	—
Antimon. hydrogen...	SbH_3	132.2	1650.4

ANTIMONY.

I. ANTIMONY AND ITS METALLOIDAL COMPOUNDS.

The metal occurs in the mineral kingdom (NATIVE ANTIMONY), but is prepared by reducing the sulphuret in several ways.

Reduction of Antimony.

1. *By metallic Iron.* Crucibles, containing granulated bar-iron (nails) free from rust, are heated to a red heat, then 2 or $2\frac{1}{2}$ times as much sulphuret of antimony (crude) added, and the whole heated to fusion. The fused mass is poured out, the metal separated from the slag (sulphuret of iron), and refused to separate more slag. $\text{SbS}_3 + 3\text{Fe} = 3\text{FeS} + \text{Sb}$. The iron combines with the sulphur, forming sulphuret of iron, while metallic antimony is set free; but the slag and antimony having nearly the same spec. grav., a white heat should be employed towards the close of the operation. The iron and crude antimony should be in equivalent quantities, for an excess of iron produces an alloy of the two metals; to free the regulus from iron, it might be heated with a little saltpeter or nitrate of soda, were it not too expensive. The more finely divided the iron the more rapid is the reduction, with less loss of crude antimony by volatilization. In any case, this method is not economical, for it yields 50–55 per cent. metal, with a loss of 22–17 per cent. It might undoubtedly be improved, for the dry assay by iron produces 63·5 per cent. antimony.

2. *By Iron and Alkali.* By mingling alkaline sulphurets with the sulphuret of iron, it becomes more fusible and specifically lighter, and obviates the difficulty of separation alluded to (1). This may be done by adding the car-

Crude antimony.....	100	100	100	100	100	100
Oxide of iron.....	40	40	58	58	80	—
Forge cinder.....	—	—	—	—	—	80
Carb. soda.....	50—100	100	10	50	—	50
Sulph. soda.....	—	—	—	—	50	—
Charcoal.....	8—10	14	10	10	17	10
Antimony obtained.....	56	65	58	66	57	60

These experiments derived from Berthier's "Essai par la voie seche" may lead to an improvement of the processes for reducing antimony from its ores. It is evident, that with lime, or its sulphate, and a rich iron ore, the materials are all economical, and that a reverberatory may be employed instead of crucibles.

Pl. III. figs. 1 and 2 represent a reverberatory for reducing antimony directly from the ore, as successfully executed by Funck at Linz in Germany. The hearth consists of well-rammed sand and clay, sloping from all sides towards the centre, where it is connected with the orifice *a*, for running out the metal, which is closed by heavy ashes; *b* is the air-channel through the bridge; *d*, *c*, the door for charging with the prepared ore and drawing off the slag; *e* the grate; *f* the door for firing; *g* the chimney. Scale 1 : 100. 2 to 3 cwt. ore require 8–10 hours heat, but the metal being very impure is refused in portions of 20 to 30 lb., covered with coal dust, in crucibles arranged in a reverberatory.

The metal obtained by these processes contains considerable quantities of iron, sulphur,

ANTIMONY.

bonated or sulphated alkali and charcoal to the mixture of metallic iron and sulphuret of antimony. $\text{SbS}_3 + 3\text{NaO} = 3\text{NaS} + \text{SbO}_3$ and $\text{SbO}_3 + \text{C}_3 = 3\text{CO} + \text{Sb}$. The following results were obtained by Berthier:

Crude antimony. 100	100	100
Iron	42	25
Dry carb. soda...	50	10
Charcoal	5	1
Antimony obtained...	65	62

From this it is evident that with the equiv. of iron, the greatest yield is obtained by using 2 crude antimony to 1 carb. soda, and $\frac{1}{10}$ of charcoal; where the quantity of soda is diminished, *cæt. par.*, the yield is less. By increasing the alkali, the quantity of the iron may be diminished, as shown in the 3d column.

Sulphate of soda, with $\frac{1}{5}$ charcoal, is reduced to sulphuret and may be substituted for soda; but the following results show that the quantity of soda must not be too great.

Crude antimony.....	100	100
Iron	42	42
Sulphate of soda	100	10
Charcoal	20	2
Antimony obtained.....	22	61

Magnetic oxide of iron, smithy slack, good forge cinders, or any rich oxide of iron may be substituted for metallic iron, employing an alkaline flux and more charcoal than is sufficient to reduce the oxide of iron. The following are Berthier's results:

Crude antimony.....	100	100	100	100	100	100
Oxide of iron.....	40	40	58	58	80	—
Forge cinder.....	—	—	—	—	—	80
Carb. soda.....	50—100	100	10	50	—	50
Sulph. soda.....	—	—	—	—	50	—
Charcoal.....	8—10	14	10	10	17	10
Antimony obtained.....	56	65	58	66	57	60

and frequently arsenic, lead, and copper. To obtain it pure, especially free from arsenic, for medical purposes, Liebig proposes the following method. Fuse 16 pts. antimony with 1 pt. sulphuret of antimony and 2 pts. dry carbonate of soda in a Hessian crucible for 1 hour, break the crucible after cooling, and carefully separate the metal from the slag. The metal is then fused again with $1\frac{1}{2}$ pts., and a third time with 1 pt. carbonate of soda. The slag of the first fusion is dark brown, of the 2d light brown, and of the 3d yellowish white. Coal should be carefully prevented from falling into the crucible. Two fusions are generally sufficient to obtain the metal perfectly pure, but the 3d insures it, except when lead is present.

The sulphuret is used to form sulphurets of iron and copper, which form fusible compounds with sulphuret of sodium. $m\text{Sb} + \text{Cu}$, Fe_2 , As and $3\text{NaO} + \text{SbS}_3 = m\text{Sb} + \text{CuS}$, 2FeS , $3\text{NaS} + \text{AsO}_3$. If the metal contain no arsenic, a part of the oxygen of the soda oxidizes a small portion of antimony which remains in the slag, but if it contain arsenic,

this metal is first oxidized and proportionally less antimony. 100 crude metal and $6\frac{1}{2}$ sulphuret yield 94 pure antimony. When the percentage of iron is high, more sulphuret of antimony must be employed, such as 8 crude metal, 2 crude antimony, and 2 carbonate, for unless the iron be wholly sulphurized the arsenic cannot be separated.

Wöhler deflagrates 10 antimony with 12 salt-peter and 15 carbonate of soda, washes out the arseniate carefully, and reduces the remaining antimoniate of potassa by black flux, but this purified metal still retains its copper and iron. Berzelius fuses 2 pts. finely powdered antimony with 1 pt. oxide of antimony, by which the other metals and sulphur (excepting lead) are oxidized and remain in the slag. A better process, according to Liebig, is to fuse 4 pts. antimony with 1 pt. binocide of manganese, and to fuse the resulting regulus with $\frac{1}{10}$ carbonate of soda during an hour.

Lead can be separated from antimony only in the humid way. For a method of freeing crude antimony from arsenic, see the **SULPHURET** below.

Properties. Commercial antimony has a grayish white color, a splendid fracture with large lamellar structure, fuses on charcoal before the blowpipe with greater difficulty than the pure metal, often gives at the first moment an arsenical odor and becomes coated with a slag of metallic sulphurets. The granular structure of the fractured surface is no test of its purity, according to Capitaine, unless in small masses, for a quantity of the pure metal fused and slowly cooled exhibits a large lamellar structure, and the impure exhibits a granular structure by rapid cooling.

Pure antimony is silver-white, with a splendid lustre, crystallizes readily by fusion, breaking the congealed surface and pouring out the still liquid metal. Cryst. Obtuse rhombohedron, nearly cubical, of $117^{\circ} 15'$ and $62^{\circ} 45'$, with perfect cleavage parallel to terminal plane, less perfect parallel to rhombic planes. It is brittle, easily pulverized. Spec. grav. = $6.702 - 6.86$. It fuses at about 800° , just below redness, and volatilizes at a white heat; if heated violently in contact with air, it burns with a brilliant white flame, giving off dense white fumes of antimonious acid, which form by condensation *flowers of antimony*. It does not change in air or water at common temperatures; but ignited in steam it oxidizes with explosive force. It takes fire spontaneously in chlorine. Organic acids, dilute sulphuric and muriatic, scarcely act on it; nitric readily oxidizes it, and it is perfectly soluble in aqua regia. Heated with nitrate or chlorate of potassa and carbonate of soda it deflagrates, forming antimoniated alkali.

The *analysis* of compounds of antimony is sometimes attended with difficulty. Its presence may be ascertained as directed in **ANALYSIS**. Its compounds heated on charcoal by the blowpipe, give off copious white fumes, especially if mingled with soda, often forming fine crystals of the oxide around the test, and coating the coal white. The usual tests are sulphuretted hydrogen and sulphhydrate of ammonium, which precipitate all the oxides as yellowish or red-

dish sulphurets from an acidulated solution; but the sulphurets are soluble in an excess of the sulphhydrate, most perfectly by digestion with the yellow stale sulphhydrate. Another test is given below under *antimoniuret of hydrogen*. To determine the quantity of metal, acidulate the solution with chlorohydric or tartaric acid to prevent milkiness upon dilution, and pass sulphuretted hydrogen through it, gently warm to expel the excess of this gas, and collect and weigh on a balanced filter; dissolve a weighed quantity of the sulphuret in chlorohydric acid after previous oxidation by nitric; collect the sulphur and weigh; collect the sulphuric acid by chloride of barium, calculate its sulphur, and subtract the sum of the two portions of sulphur from the sulphuret; the balance is metallic antimony. Or heat the sulphuret in a stream of sulphuretted hydrogen in an apparatus as represented in Fig. 24 under **ANALYSIS**, excepting that *ef* is a single tube with a bulb blown in the middle at *i*, into which bulb the sulphuret is introduced, weighed, and reduced; the residue is metallic antimony.

To separate antimony from other metals, a practical but not accurate method, with an alloy, is to dissolve in nitric acid, evaporate nearly to dryness, and dissolve in water; nearly all the oxide of antimony remains undissolved, together with the oxide of tin. To separate it from nearly all other metals, except tin and arsenic, precipitate by sulphuretted hydrogen from an acidulated solution and digest the precipitate with sulphhydrate of ammonia, which should contain free sulphur; the sulphuret of antimony dissolves. To separate it from arsenic, see **ARSENIC**. To separate it from tin, obtain both in the state of oxides (SbO_3 and SnO_2), weigh them, dissolve in chlorohydric acid, and precipitate the antimony by a bar of metallic tin, with the assistance of a little warmth, taking care to keep the solution acid, filter and weigh the metallic antimony; the balance is tin, after reducing the mixed oxides to metal by calculation. Or digest the mixed and weighed oxides for some time in tartaric acid or bitartrate of potassa, which dissolves out the oxide of antimony.

Antimony is thrown down from its solutions in the metallic state by lead, tin, cobalt, cadmium, iron, and zinc.

Uses. Besides its use for making chemical preparations of antimony, it is largely employed in certain alloys of lead and tin, to impart to them greater hardness. See **BRITANNIA METAL**, **FEWTER**, **TYPE METAL**.

Alloys. Antimony unites readily with other metals, either by direct fusion or when one or both are in their nascent state, generally forming harder and more brittle metals.

Potassium or Sodium. These two metals readily alloy with antimony in a similar manner. By heating tartar emetic (tartrate of antimony and potassa) strongly for several hours in a well-closed crucible, an antimonuret of potassium is formed, mingled with carbon. If, previous to heating, some of the carbon be burned off, either by calcination or by mixing it with $\frac{1}{10}$ its weight of nitre, the alloy is obtained in a button. It is more easily obtained and more highly charged with potas-

sium by heating an intimate mixture of equal parts of carbonized cream of tartar and metallic antimony. This alloy is softer and less brittle than antimony, and much less volatile, decomposes water and alcohol, and heats spontaneously in the air, burning combustibles on which it is placed; it contains about $\frac{1}{5}$ its weight of potassium.

A pyrophorus is formed by heating 100 pts. tartar emetic with 3 pts. lamp-black in a closed crucible for 3 hours, suffering it to cool for 6 or 7 hours, and quickly putting it in a broad-mouthed and well-stoppered bottle, without the slightest contact of moisture. If taken out before cooling it explodes, but when well prepared will keep for years. It detonates when brought in contact with the least moisture.

Double antimoniuress of potassium may be obtained by adding to the above mixtures other metals or other oxides.

Arsenic and antimony heated together combine in all proportions with evolution of light. The compound of

Sb.....	129.24	63.17
As.....	75.34	36.83

is fusible at commencing redness, grayish-white, compact, tenacious, of a granular and crystalline texture. *Berthier*. An arsenical antimony occurs as a mineral. Other alloys see under COPPER, GOLD, IRON, LEAD, SILVER, TIN.

1. *Oxide of Antimony*. Syn. Protoxide of antimony, Hypanimonious acid. *Lat.* Vitrum antimonii, Antimonium oxydatum vitrificatum, Oxidum Stibicum. *Ger.* Spiessglanzoxydul (the impure), Spiessglanzglas. A grayish black suboxide appears to form by long exposure of metallic antimony to moist air, and also by the galvanic battery.

2. Oxide of antimony occurs as a mineral, see OXIDE OF ANTIMONY. It is prepared, 1, by digesting 1 pt. metallic antimony with 2 pts. nitric acid, diluted with 4 pts. water, and washing the oxide until the water ceases to give an acid reaction. 2. Dissolve sulphuret of antimony in muriatic acid in a retort, distil off the acid and water, and then the chloride of antimony into a clean receiver; this chloride is decomposed by water, the precipitate boiled with carbonate of soda, washed with water, and dried. 3. To make an oxide for the preparation of tartar emetic, defflagrate a mixture of 6 antimony, 3 saltpeter, and 2 bisulphate of potassa, throwing it portionwise into an ignited crucible. The oxide is in crystals, which are boiled

with pure water to remove sulphurets of antimony and arsenic, then with water acidulated with sulphuric acid. The oxide is then wholly soluble in bitartrate of potassa, and, if iron were present it remains undissolved, if oxide of antimony were in excess; boneblack removes the iron from the tartar emetic. *Preuss.*

4. Keep metallic antimony fused in a deep crucible in a slightly inclined position; the oxide coats the metal, and at a high temperature sublimes to the upper portions of the crucible, in the form of brilliant white needles.

Properties. Pure oxide of antimony is of a brilliant white color, that prepared in the liquid way pearly white; it crystallizes in 2 forms, the regular octahedron and prismatic, both of which may be observed together in the sublimed crystals of process 4. *Mitscherlich* (*Pogg. An.* xlix. 409) has shown that octahedra may be obtained by dissolving oxide of antimony in a boiling solution of caustic soda to saturation, and cooling the solution slowly in a stoppered vessel; and that by mixing boiling solutions of carbonate of soda and terchloride of antimony the precipitate is prismatic; if the solutions be mixed cold, the precip. appears to be octahedral. Oxide of antimony is therefore dimorphic, and it is isodimorphic with arsenious acid. It is probably *allotropic*, for *Berzelius* observes that by dissolving oxide of antimony in bitartrate of potassa, two kinds of salts are produced, the one crystallizing (tartar emetic), the other drying to a gummy mass, in both of which the metal is in the same state of oxidation. (See TARTRATE of Antimony and Potassa.) Spec. grav. 5.56. By heat it becomes yellow, fuses at a red heat to a yellowish liquid, which congeals to a pearl-gray, crystalline mass; it may be sublimed at a higher temperature. Heated in the air it oxidizes to antimonious acid. It is easily reduced to the metallic state by charcoal or hydrogen. It is somewhat soluble in water without action on litmus, but does not form a hydrate.

It appears to act the part of a feeble acid towards the alkalies, although, according to *Mitscherlich*, these compounds cannot be obtained in the liquid way. The oxide is soluble in dilute caustic alkali, the solution absorbing oxygen to form antimonites. Fused with carbonated alkali it expels the carbonic acid, forming KO (NaO) + SbO₃; but these compounds treated with water separate into caustic alkali and insoluble oxide of antimony. It is the only oxide of antimony forming salts with acids.

	H = 1	O = 100	In 100 pts.		Berz.	J. Davy.
Sb.....	129.2	1612.9	84.32	100	84.319	85
O ₃	24	300	15.68	18.6	15.681	15
	153.2	1912.9	100	118.6	100	100

Form., SbO₃ (Sb₂O₃, *Berz.*).

Uses. The salts of oxide of antimony have been tried in manifold ways in medicine, and a few of them are still extensively employed. A proposition has lately been made to prepare oxide of antimony from the sulphuret and employ it as a substitute for white-lead.

2. *Antimonious acid*. Syn. *Lat.* Acidum

Stibiosum. *Ger.* Antimonige oder Spiessglanzige Säure.

Prep. 1. Oxidize antimony by nitric acid, evaporate to dryness, and ignite; 2. ignite strongly antimonious acid; 3. calcine sulphuret of antimony thoroughly in the air.

Prop. A snow-white powder, becoming yellow by heat, but infusible and not volatile, more

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difficult to reduce than the oxide. Fused with caustic or carbonated alkali, it forms a soluble antimonite from the solution of which acids precipitate hydrated antimonious acid; this acid is slightly soluble in water, has an acid reaction, contains 5.26 per cent. water (the ignited is insoluble and does not redden litmus).

	H = 1	O = 100	In 100 pts.		Berz.	Thomson.	Thénard.
Sb	129.2	1612.9	80.13	100	80.127	80.84	80
O ₄	32	400	19.87	24.8	19.873	19.16	20
	161.3	2012.9	100	124.8	100	100	100

Form., SbO₄ (Sb₂O₄, Berz.). The hydrate = SbO₄ + HO. Mitscherlich endeavored to prove that it is not a true acid, but an antimoniate of oxide of antimony, thus 2 SbO₄ = SbO₃ + SbO₅ (similar to hyponitric acid), and that it is decomposed by alkalies in the oxide of antimony and antimonious acid.

Use. Some of its compounds employed to give a yellow color to glass, or with oxide of iron an orange. See its salts below.

3. *Antimonic acid*. Syn. Lat. Acidum Stibicum. Ger. Spiessglanzsäure.

Prep. 1. Dissolve antimony in aqua regia, evaporate to dryness, add nitric acid, and heat it to a point below redness to remove the nitric acid. 2. Mix 1 pt. powdered antimony with 4—5 pts. saltpeter, project the mixture portionwise into an ignited crucible, wash with water, extract the alkali by nitric acid, dry, and heat it to below ignition.

Prop. A light yellow powder, by heat be-

	H = 1	O = 100	In 100 pts.		Berz.	Proust.	Thomson.
Sb	129.2	1612.9	76.34	100	76.34	77	73.33
O ₅	40	500	23.66	31	23.66	23	26.77
	169.3	2112.9	100	131	100	100	100

Form., SbO₅ (Sb₂O₅, Berz.).

Use. The antimoniate of lead is employed as a pigment, Naples yellow. See its salts below.

1. *Sulphuret of Antimony*. Syn. Antimony ore, Crude Antimony, Sesquisulphuret of Antimony. Lat. Sulphuretum Stibicum, Stibium sulphuratum nigrum, Lupus metallorum. Ger. Schwefelspiessglanz, Anderthalb-Schwefelantimon, Rohes Antimon. The Greek and Latin names now applied to the metal formerly designated this sulphuret.

Eliques of Crude Antimony.

The sulphuret of antimony is generally disseminated in a quartzose gangue, from which it is separated by eliquation, advantage being taken of its fusibility over that of its associated substances. From the great brittleness of the sulphuret the ore cannot easily be subjected to the operations of stamping and washing to obtain it richer, although Berthier has shown that such a preparatory step would give a greater yield of crude antimony, his experiments on a small scale having produced 72 per cent. of pure sulphuret from a rich ore.

1. The oldest method of running out crude antimony, and still practised in Hungary, consists in throwing coarsely-broken ore into a

It is slightly soluble in oil of vitriol, not in nitric, easily in chlorohydric acid, from which water precipitates it; it is soluble without change in alkaline sulphurets, sulphuretted hydrogen being evolved; by fusion with metallic antimony it is reduced to oxide.

coming darker yellow, by ignition losing oxygen and becoming antimonious acid; insoluble in water and of neutral reaction; combustible abstract oxygen by ignition with it and reduce it to a lower oxide or to metal. It does not decompose the carbonated alkalies in the humid way, but expels carbonic acid by fusion with them; it is soluble in boiling caustic alkali. Acids precipitate from these solutions white hydrated antimonious acid. The hydrate is also obtained by the above processes, by omitting the final heating. It is slightly soluble in water, reddens litmus, contains 5.09 per cent. water, is soluble in caustic alkali and strong chlorohydric acid; the latter solution is precipitated by the successive addition of small quantities of water, but not by immediately adding a large quantity; it is soluble without change in the alkaline sulphurets, with the evolution of sulphuretted

large pot or crucible, perforated on the bottom, which is set upon a smaller one; the latter is buried in the earth, the upper one closed with a cover and luted, and a fire built around it. The crude antimony flows through the perforations into the lower vessel, and the gangue, mixed with some sulphuret, remains in the upper vessel. The process is very defective in economy.

2. An improvement of this process consists in placing a large number of eliquation pots (pots de charge) in a circular reverberatory, the receiving pots (pots à boulet) on the outside of the furnace, and connected with the former by curved earthenware tubes. The pots can be emptied and recharged without cooling the furnace. Pl. IV. figs. 1, 2, and 3 exhibit such a furnace as employed in France. *aaa* represent the pots for containing the mineral; *bb* the curved tube through which the sulphuret flows into the recipients *ccc*, all of which are earthenware; *d* the grate of the furnace; fig. 3 is the enlarged pot, conducting-tube, and recipient.

3. Pl. IV. figs. 4 and 5 represent a reverberatory employed in Dep. Vendée in France; *a* fire-place; *b* bridge; *c* hearth on which the mineral is placed; *d* substratum of the hearth; *e* conducting-tube; *f* recipient; *g*, fig. 5, the grate.

The simplicity of this arrangement, with the usual advantages of a reverberatory, deserve the attention of the metallurgist, for it might be so improved as to supersede other arrangements. With a rich ore a charge of 8 cwt. ore yield 4 cwt. crude antimony, and the 3 charges of a summer's day consumed 80 cub. ft. wood.

4. Pl. III. figs. 3, 4, and 5 exhibit the arrangement contrived by M. Panzerat of Alais, and employed at the mines of Malbosc in Ardèche, France. Fig. 3, the ground plan taken at the height of the flues *gg* in the line *EF* of fig. 4; fig. 4 a vertical section taken in the line *AB* of fig. 3; fig. 5 another vertical section in the line *CD* of fig. 3. *abc* are 3 grates, $4\frac{1}{2}$ ft. long by nearly 1 ft. broad, between which are 2 square galleries, *de*, running through the furnace and separated from the fire-places by walls having alternate openings, *fgh*, the ends of the galleries being closed by iron doors, *ii*. In each gallery are two conical crucibles of cast-iron into which the crude antimony flows, and to prevent its adhesion they are coated with clay; they rest on iron stands running on 4 wheels, to remove them from the gallery. Both galleries are covered with flat tiles of fire-brick *ll*, which serve at the same time as basis for the upright and slightly conical fire-clay cylinders, *mm*, for the eliquation; the tiles are somewhat bent towards the centre to receive the lower part of the cylinders, which have a small opening, *n*, through which the sulphuret flows into the iron recipients; *o* are orifices several inches in height, turned outward, by which the cylinders may be reached from the front and back part of the furnace by conical openings, *pp*, in the walls; the orifices, *o*, are closed with clay stoppers during working, and opened to draw out the gangue and slags. The cylinders pass through openings in the furnace arch, *qq*, which are a little larger than the cylinders, and are covered with clay covers, *rr*. The arch at the top, *ss*, is arched cylindrically, forming a double cross-arch. The flame, after playing around the cylinders, passes out through 3 openings and flues into the chimney, *t*; *u* is one opening, *v* the other two, provided with valves. *W* is a chimney for conducting off antimonial fumes, which arise while drawing out the slags and exhausted ore; another chimney, *x*, begins above *yy*, where the cylinders are charged; a partition-wall, *z*, divides the chimney into 2 parts, so that the workman while operating on one side is not inconvenienced by the fumes of

the other side; *a'a'* and *b'b'* are iron and wooden beams and bands to brace the chimneys; *c'c'* conical arches on both sides of the furnace, closed with well-fitting plates, *d'd'*, designed to observe from time to time the condition of a cylinder and to repair it. Each cylinder is charged with 490 lbs. ore, previously warmed on the arch; the coarsest and richest ore is placed at the bottom; as soon as the eliquation is completed, the slags and exhausted ore are drawn out through the openings *o*, and the cylinders recharged. The antimony should have a blue color and not a red, for the latter indicates too high a heat. When the iron recipients are $\frac{3}{4}$ filled, they are drawn out, cooled, and the lump of crude antimony, weighing about 88 lbs., removed. The charges are made every 3 hours, and about 100 lbs. crude antimony can be obtained per hour, when in successful operation. The cylinders last on an average some 20 days. The quantity yielded is said to be 50 per cent. crude antimony. This furnace is superior to all others hitherto employed in smaller consumption of fuel, less labor, and more perfect eliquation.

Prepared on a large scale, the sulphuret of antimony (crude antimony) is never pure, but contains variable quantities of sulphurets of lead, iron, copper, and arsenic, so that its streak is usually black instead of reddish-black. These metals may be detected in the usual way by qualitative analysis.

To prepare the sulphuret pure in the dry way, fuse 13 pts. pure antimony with 5 pts. flowers of sulphur in a crucible, adding the mixture portionwise, and pour out the sulphuret. The little regulus uncombined may be easily detached.

Properties. Pure sulphuret of antimony is steel-gray, the native darker, of a shining metallic lustre, with a fibrous crystalline structure, brittle, with a reddish black streak; easily fusible, but less so than the metal, boils at a high temperature, and partially distils in a current of gas; at a white heat in crucibles, loses 10–12 per cent. sulphur. Calcined in the air it is oxidized; at a white heat with charcoal sulphuret of carbon passes off and the metal remains. Ignited in a current of hydrogen it is entirely sulphurized, and many metals rob it readily of its sulphur by ignition. It is more readily dissolved by acids than the metal; heated with strong chlorohydric it evolves sulphuretted hydrogen. It fuses unchanged with oxide of antimony.

	H = 1	O = 100	In 100 pts.	Berz.	Thomson.	Bergman.	J. Davy.
Sb	129.2	1612.9	72.77	72.8	73.77	74	74.16
S ₃	48.3	603.5	27.23	27.2	26.23	26	25.84
	177.5	2216.4	100	100	100	100	100

Form., SbS_3 (Sb_2S_3 , Berz.).

It combines in a few cases as a sulphobase with a higher metallic sulphuret, but usually acts as a sulpho-acid, forming *Hyposulphantimonites*, many of which are found in the mineral kingdom. (See ANTIMONIAL ORES above and SULPHOSALTS below.)

Use. Its principal use should be to prepare metallic antimony, but it is often improperly

employed in its crude and impure state for pharmaceutical preparations. The presence of lead, copper, and arsenic should prevent the latter use. Lead may be detected, when present in some quantity, by needle-shaped crystals of chloride of lead, after cooling the solution in chlorohydric acid; or after acting upon it by dilute nitric acid, it will remain with sulphur, &c., as a sulphate of lead; copper shows itself

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in the chloride solution by its blue color, especially after the addition of ammonia. To detect arsenic, dissolve in chlorohydric acid until sulphuretted hydrogen ceases, boil again with the same acid, add tartaric, wash the residue, and test it as sulphuret of arsenic.

Weigand states that it may be almost wholly freed from sulphuret of arsenic by pulverizing and washing over to get the finest powder, by pouring over this twice as much by weight of ammonia and shaking it frequently during 48 hours. *Berz. Jahrb.* xxi. 116.

Sulphuret of Antimony prepared in the humid way. 1. Precipitate a solution of tartar emetic by sulphuretted hydrogen or a sulphhydrate; the precipitate is of a fiery red color and is the sulphuret (according to Liebig it is the hydriated sulphuret).

2. Digest Kermes-mineral, with warmth, with a solution of tartaric acid, which extracts oxide of antimony and potassa, if present.

3. Digest 1 crude antimony, 1 pearlsh, and $1\frac{1}{2}$ dry slacked lime, with 15 water in a closed vessel for 2 hours, filter, dilute largely, add dilute sulphuric acid as long as it precipitates, boil the precipitate with the same dilute acid, and wash with water. It is a loose and light, amorphous powder, with a bright, brown color, and a reddish-brown streak, inodorous and tasteless, loses all hygroscopic moisture at 212° , fuses to common gray sulphuret without loss of weight, readily calcines into antimonious acid and oxide; it is completely soluble in caustic, carbonated, and sulphuretted alkali; kept several days in chlorohydric acid at common temperatures, it passes from its colored amorphous state into that of the gray crystallized sulphuret. If, by warm digestion with tartaric acid, it evolve sulphuretted hydrogen, it indicates the presence of an alkaline sulphuret; if the precipitate produced by sulphuretted hydrogen in the tartaric solution be bright red, oxide of antimony was present. (*Liebig.*)

Kermes-mineral. Is the precipitated sulphuret of antimony frequently containing a sulphantimoniated alkaline sulphuret and oxide of antimony. The presence of the latter was believed to be essential to its constitution, and hence Liebig's view that it is an oxysulphuret of antimony, $\text{SbO}_3 + 2\text{SbS}_3$; the researches of Berzelius, and lately of Rose, have shown that it is essentially sulphuret of antimony.

Prep. 1. One part pure carbonate of potassa is well mingled with $2\frac{2}{3}$ pts. finely powdered sulphuret of antimony, and slowly heated in a covered crucible until it fuses without boiling; it is the *hepar antimonii*, deliquescent and of a liver-brown color; boil it with water and filter through a filter heated to 212° ; the kermes separates on cooling. If the clear liquid from which the kermes has precipitated be boiled over the first insoluble residue, it dissolves more kermes, and by repeated boiling leaves finally a residue of oxysulphuret.

2. It may also be prepared by fusing 2 metallic antimony, 1 sulphur, and 3 carbonate of soda, or 16 crude antimony, 3 sulphur, and 32 carbonate of potassa, or by heating 3—4 pts. cream of tartar and 1 crude antimony in a

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crucible until the vapors of decomposed tartaric acid disappear; the mass is boiled and filtered as before.

3. By boiling sulphuret of antimony in powder with a solution of carbonated or caustic alkali.

Theory of its formation. The kermes obtained by boiling with dilute carbonated alkali contains no oxide of antimony. Rose found that when there was more alkali than the sulphuret of antimony could saturate, it consisted of

Antimony	69.00
Potassium	2.25
Sulphur	28.41
	99.66

The sulphur is just sufficient to form KS_3 and SbS_3 ; there was, however, no KS_3 present but KS , SbS_3 , which did not appear to be combined with the sulphuret of antimony. When the concentrated carbonated alkaline solution is boiled to saturation with the crude antimony, the kermes which separates on cooling, contains oxide of antimony, the first portion less, the latter more oxide; but when examined, after washing and drying, by a compound microscope, the crystals of oxide of antimony and the flocculæ of the kermes are very distinct. In a dilute alkaline solution the oxide remains dissolved, while a strong solution dissolved more, which separated in part and slowly on cooling. A portion of the sulphuret of antimony exchanges sulphur for oxygen of the potassa (or soda), forming some sulphuret of potassium and oxide of antimony, so that the hot solution contains hyphantimonite of potassa and hypo-sulphantimonite of potassium.

When kermes is formed by fusion of the sulphuret and carbonated alkali, the same interchange takes place, but a portion of crude antimony is reduced to the metallic state, the sulphur which it lost having united with a portion of sulphuret of antimony to form the higher sulphuret SbS_5 .

Kermes formed by boiling the sulphuret with caustic potassa does not contain a trace of oxide, but is a compound of KS , $\text{SbS}_3 + 2\text{SbS}_3$, and by continued washing with boiling water is reduced to KS , $\text{SbS}_3 + 4\text{SbS}_3$.

Use. Kermes was known to Glauber, and introduced into medicine as a secret remedy in 1707, when it was purchased and published by the French government. It is still employed in medicine. (See SULPHOSALTS below.)

2. *Oxysulphuret of Antimony.* Syn. Oxy-sulphuretum stibicum, Crocus of Ant. Ger. Antimonsafran, Vitrum antimonii, Glass of Ant. Ger. Spiessglangglas. This compound is found as a mineral (see RED ANTIMONY), but the artificial crocus and glass of antimony are the same in a more or less impure state.

Crocus of A. 1. Prepared by deflagrating portionwise equal parts saltpeter and crude antimony in a heated iron crucible or mortar, removing the upper layer (liver of A.) and lixiviating the lower with water; the saffron powder is oxysulphuret, containing hyphantimonite of potassa.

2. Digest crude A. with chlorohydric acid

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inodorous and tasteless, perfectly soluble in alkali; very unstable in its isolated condition, giving off its sulphur by heat and being reduced to the sulphuret, SbS_3 . Bisulphuret of carbon likewise reduced it to the same by removing sulphur. It forms sulphosalts with sulphobases, which see below.

	H = 1	O = 100	In 100 pts.
Sb.....	129.2	1612.90	61.59
S ₈	80.5	1005.83	38.41
	209.8	2618.73	100

	H = 1	O = 100	In 100 pts.
SbO ₃	153·2	1912·9	30·14
2 SbS ₃	355·0	4432·8	69·86
	508·2	6345·7	100

Use. Formerly employed in medicine, but now discarded.

Antimoniuretted Hydrogen. Ger. Antimonwasserstoff. Prep. 1. Fuse 2 pts. zinc with 1 pt. antimony, add water and sulphuric acid. *Capitaine.* The gas is mixed with hydrogen. 2. A better method is to add a little sulphuric acid to a saturated solution of tartar emetic and dissolve zinc in it. *Wöhler.* A colorless gas, combustible, insoluble in water, neutral. It precipitates salts of mercury and of many metals, but not copper, by which it is distinguished from arseniuretted hydrogen. It closely resembles the latter gas in constitution and decomposition. When burned it forms water and deposits black metallic antimony or the oxide, and might hence be confounded with arseniuretted hydrogen. See Testing for ARSENIC. Formula, SbH_3 .

The oxysulphurets are very fusible; they combine with earthy silicates and corrode crucibles as powerfully as litharge; hence the commercial articles usually contain silica and alumina.

3. *Sulphantimonious Acid*. Syn. Tetrasulphuret of A., Sulphidum stibiosum, Antimoniges Sulfid. *Berz.* Dissolve antimonite of potassa or soda in chlorohydric acid, dilute largely with water, and pass sulphuretted hydrogen through the liquid. A fiery red precipitate, soluble in chlorohydric acid with evolution of sulphuretted hydrogen and a residue of sulphur; heated dry it evolves sulphur, leaving the sulphuret. If tartaric acid be added to the chlorohydric solution of the antimonite, sulphuretted hydrogen precipitates the next acid (4).

	H = 1	O = 100	In 100 pts.	<i>H. Rose.</i>
Sb..	129.2	1612.9	66.72	66.14 66.55
S ₄ ..	64.4	804.66	33.28	33.86 33.45
	193.7	2417.56	100	100 100

4. *Sulphantimonic Acid*. Syn. Persulphuret of A. Golden sulphuret of A. *Lat.* Sulphidum stibicum, Sulphur auratum antimonii. *Ger.* Spiessglanzschwefel, Goldschwefel, Antimonsulfid, *Berz.* A-persulfid, *Liebig.*

Prop. A light amorphous powder of a lively orange color (often with a brownish red tint).

II. SALTS.

The salts of antimony not wholly insoluble have a feeble metallic taste, the soluble are generally clouded by dilution with water; the haloid and oxysalts are precipitated with a red or brownish color by sulphhydrates, the sulphosalts with the same or a yellow color by acids.

HALOID SALTS.

Chloride of Antimony	SbCl_3	235.7
Oxychloride.....	$\text{SbCl}_5 + 3 \text{SbO}_3 + 3 \text{HO}$ or $2 \text{SbCl}_3 + 9 \text{SbO}_3$	271.2
Tetrachloride.....	SbCl_4	
Perchloride	SbCl_5	306.7
Bromide	SbBr_3	
Iodide.....	SbI_3	
Fluoride	SbF_3	

1. *Chloride of Antimony.* Syn. Sesquichloride of A., Butter of A. Lat. Chloretum stibicum, Oleum seu Butyrum antimonii, Cauticum antimoniale. Ger. Antimonchlorid, Berz.; A. chlorür, Liebig; Spiessglanzbutter, Salzsaures Spiessglanzoxydul.

Prep. Mix $3\frac{1}{4}$ pts. corrosive sublimate with 1 pt. finely powdered metallic antimony, or 7 pts. corr. sublim. with 3 pts. sulphuret of antimony, and distil in a retort. The chloride passes over and metallic or sulphuret of mercury remain; in the former case, the brown color, according to Capitaine, is due to an arsenio-chloride of arsenic. 2. For technical

purposes dissolve antimony or its oxide in sulphuric acid, evaporate to dryness, mix it with a little more than twice its weight of common salt, and distil. *Berz.* Or for the same uses; 3. Dissolve 1 pt. finely powdered sulphuret of A. in 5 pts. strong muriatic acid (22° Beaumé) with a gentle heat, until all the sulphuretted hydrogen is expelled, evaporate in porcelain until a test drop put on a glass-plate crystallizes; then transfer to a retort, distil until a drop put on a cold metallic surface begins to congeal, and distil the residue into a clean receiver.

Prop. White, semi-transparent, crystalline, of buttery consistence, fuses at 162°, flowing like an oil, boils at 446°, *Capitaine*; exposed to the air, it fumes slightly, attracts water, becomes liquid; with more water it precipitates a white powder, the oxychloride, which is soluble in an excess of chlorohydric acid; a previous addition of tartaric acid prevents the precipitation. Heated with nitric acid, it is converted into antimonic acid, with chlorine into perchloride; heated with sulphocyanide of potassium, it forms sulphantimonious acid, mellonide of potassium, while sulphuret of carbon is evolved. Dry fused chloride absorbs ammonia, forming a brittle solid. *Rose.* Sulphuretted hydrogen passed through a solution of the chloride in muriatic acid, forms, at first, a yellow precipitate containing 5—6 per cent. chloride; when dilute, it is pure sulphuret. *L. Gmelin.*

	H = 1	O = 100	In 100 pts.	<i>Göbel.</i>	<i>H. Rose.</i>
Sb..	129.2	1612.90	54.84	54.98	53.27
Cl ₃ ..	106.5	1327.95	45.16	45.02	46.73
	235.7	2940.86	100	100	100

Form., $\text{SbCl} (\text{Sb}_2\text{Cl}_3, \text{Berz.})$.

Uses. Rarely employed in medicine as a caustic. It fumes more strongly than the pure chloride, being a solution of oxide or chloride in muriatic acid, is oily, of spec. grav. 1.35—1.4. The same solution is also employed for browning iron, gun-barrels, &c., and is then termed *Bronzing salt*. It is mingled with olive-oil, rubbed over the iron slightly heated, and exposed to the air till the desired color is attained; the operation of the bronzing salt is sometimes hastened by following it with nitric acid. When browned, the surface of iron is polished by a burnisher, or by wax, or by a varnish of 2 oz. shellac and 3 drachms dragons blood dissolved in 2 quarts spirit of wine. The brown color is chiefly due to peroxide of iron, and hence other metals are employed often containing copper.

2. *Oxychloride of A.* Syn. Powder of Algaroth, Mercury of Life. *Lat.* Oxychloretum Stibicum. *Ger.* Basisches Antimonchlorid. *Berz.*

Prep. Add water to the preceding; or dissolve sulphuret of antimony in muriatic acid until all the sulphuretted hydrogen is expelled, and after cooling add water in small portions until it becomes cloudy, filter, and add 5—10 times as much water; wash the precipitate until the water has no acid reaction.

Prop. A heavy, white amorphous powder, but if the precip. be allowed to remain several hours in the water previous to washing, or if

a little boiling instead of cold water be added, the salt becomes crystalline or crystallized. Decomposed by heat, chloride of A. passing over and the oxide remaining; carbonated alkali extracts chlorine, converting the whole into oxide, which retains alkali; continued boiling or washing also decomposes it.

Berzelius calculates from Phillip's analysis the formula, $\text{SbCl}_3 + 3\text{SbO}_3 + 3\text{HO}$; but from the more recent analyses of Malaguti and Johnson, it would appear to be $2\text{SbCl}_3 + 9\text{SbO}_3$.

3. *Tetrachloride of Antimony.* Syn. Bichloride of A. *Ger.* Antimonsuperchlorür, *Berz.* Known only in solution; made by dissolving antimonious acid in concentrated chlorohydric to saturation. A yellow solution, easily decomposed. Form., $\text{SbO}_4 (\text{Sb}_2\text{O}_4, \text{Berz.})$.

4. *Perchloride of Antimony.* Syn. Permuriate of A., Pentachloride of A. *Lat.* Chloridum Stibicum. *Ger.* Antimonsuperchlorid, *Berz.*

Heat powdered antimony gently in chlorine, or pass the gas over the metal; the perchloride distils over as a colorless or faint yellowish liquid, which fumes in the air with a disagreeable odor, deliquesces, forming crystals of the perchloride with crystal-water. The crystals attract more water and become liquid. Suddenly mixed with much water it becomes heated, hydrated antimonic acid precipitates, and chlorohydric acid remains in solution. *Rose.* It absorbs olefiant gas, becoming heated, and is resolved into chloride of antimony and chlorine-ether. *Wöhler.*

It unites with phosphuretted hydrogen to a red solid, with evolution of some chlorohydric acid; water expels the phosphur. hydrogen.

It absorbs also dry ammonia, forming a brown compound, which becomes colorless by sublimation without change.

	H = 1	O = 100	In 100 pts.	<i>H. Rose.</i>
Sb ..	129.2	1612.9	42.16	40.56
Cl ₅ ..	177.5	2213.26	57.84	59.44
	306.7	3826.16	100	100

Form., $\text{SbCl}_5 (\text{Sb}_2\text{Cl}_5, \text{Berz.})$.

Bromide of Antimony. Antimonbromid, *Berz.* Throw small pieces of metallic antimony into bromine in a retort; they unite with combustion; when saturated, distil over. Colorless needles, fusing at 194°, boiling at 518°, deliquescing in the air, decomposed by water. Form., $\text{SbBr}_3 (\text{Sb}_2\text{Br}_3, \text{Berz.})$.

Iodide of Antimony. Antimonjodid, *Berz.* Ant. and iodine unite also without heat to a dark-red fusible solid, which may be distilled over, and decomposes by water into iodohydric acid and oxide of antimony. Brandes says that the distilled liquid congeals to an almost vermilion-red shining mass, which water decomposes into a brown liquid and a precipitate of basic iodide. Form., $\text{SbI}_3 (\text{Sb}_2\text{I}_3, \text{Berz.})$.

Iodo-sulphuret of A. Formed by subliming at a very gentle heat equal parts of dry sulphuret of ant. and iodine. The red vapors condense to transparent shining red crystalline scales, of a disagreeable odor and taste, decomposed by water into iodohydric acid, oxide of antimony, and sulphur. It appears from the analyses of Henry and Garot to be $\text{Sb}, \text{S}_3, \text{I}_3$.

ANTIMONY.

Fluoride of Antimony. *Fluorantimon*, Berz. Dissolve oxide of antimony in fluoro-hydric acid and evaporate. Colorless crystals, soluble in water. Form., SbF_3 . There are also a tetrafluoride, SbF_4 , and a perfluoride, SbF_5 , soluble in water, which yield double salts with metallic fluorides. *Antimonofluoride of potassium* is very soluble in the liquid with an excess of acid; by slow evaporation it yields prismatic crystals, which fall to powder by rapid desiccation.

OXYSALTS.

Salts of Oxide of Antimony.

In the neutral salts there are 3 equivs. of acid to one of the oxide. They are colorless with a colorless acid; difficultly soluble in water, and with much water (especially hot) are generally separated into oxide or a basic salt and an acid salt, which can be prevented by the addition of tartaric acid. Their acid solutions are precipitated white by caustic and carbonated alkali, yellow by sulphuretted hydrogen, reddish brown by alkaline sulphurets, in an excess of which the precip. sulphuret is soluble; iron, zinc, and tin wholly precipitate the metal as a black, pyrophoric powder. The most important double salt of tartaric acid, with antimony and potassa, tartar emetic, is a $\frac{2}{3}$ basic salt. (See under *TARTRATE*.)

Oxide of antimony fused with carbonate of potassa or soda expels the carbonic acid and forms definite compounds in which the oxide of antimony seems to act the part of an acid, and the salts may be termed *hypantimonites*. The oxide freshly precipitated from the chloride and digested with strong caustic potassa, soda, or ammonia, forms these compounds. They are nearly insoluble in water. Form., KO (NaO or NH_4O) + SbO_3 . Other hypantimonites have not been examined.

1. *Sulphate of Antimony.* Syn. Lat. *Sulphas Stibicus*. Ger. *Schwefelsaures Antimonoxyd*.

Prep. Boil antimony with oil of vitriol; sulphurous acid is evolved and a white saline mass remains, which is the neutral sulphate. Water decomposes into a soluble acid salt and an insoluble basic salt; the solution evaporated, yields needle-shaped crystals of the former, which are deliquescent. The neutral salt is soluble in somewhat diluted sulphuric acid, from which water throws down, according to Brandes, a basic salt, $\text{SbO}_3, \text{SO}_3$, but the acid is wholly removable by boiling water. Form. of the neutral salt, $\text{SbO}_3 + 3\text{SO}_3$.

Eq. 273.5 (3416.4, O = 100). $\text{SbO}_3, 55.99 + \text{SO}_3, 44.01 = 100$.

2. *Sulphite of Antimony.* Syn. *Sulphis Stibicus*. Ger. *Schwefligsaures Antimonoxyd*. Digest oxide of antimony with liquid sulphurous acid, or pass sulphurous acid gas through chloride of antimony. A white powder insoluble in water. Form., $\text{SbO}_3 + 3\text{SO}_2$.

Nitrate of Antimony. Syn. *Nitras Stibicus*. Ger. *Salpetersaures Antimonoxyd*. Concentrated nitric acid attacks antimony in the cold, the dilute by boiling; both water and acid are de-oxidized and nitrate of ammonia formed. With little acid, nearly all the metal is precipitated as a basic salt; the solution retains a small

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quantity, part of which deposits as fine crystals on the glass. The whole of the acid may be removed from the salt by repeated digestion with water.

1. *Phosphate of Antimony.* a. *Neutral*. *Phosphas Stibicus*. Ger. *Neutrales phosphorsaures Antimonoxyd*. Formed by digesting oxide of A. with phosphoric acid. Form., $2\text{SbO}_3 + 3\text{PO}_5$. Brandes says that if the acid be saturated, there is formed a crystallized neutral salt containing 4 per cent. or 2 eq. water.

b. *Phosphate of A., Basic*. Formed, according to Brandes, by washing the neutral salt with cold water, which leaves the basic salt as a white powder. Form., $2\text{SbO}_3 + \text{PO}_5$. According to the same chemist, another basic salt, $4\text{SbO}_3 + \text{PO}_5$, is obtained by boiling the preceding with water. It may be a mixture of oxide and the basic salt. Berz.

2. *Phosphite of Antimony.* Syn. *Phosphis Stibicus*. Ger. *Phosphorigsaures Antimonoxyd*. Precipitated by mixing solutions of tartar emetic and terchloride of phosphorus. It is colorless and when heated evolves pure hydrogen, becoming phosphate of antimony. Form., $2\text{SbO}_3 + 3\text{PO}_3$.

Salts of Antimonious Acid.

Antimonites. Antimonious acid forms neutral and acid salts; the neutral alkaline salts are soluble; all others, acid and neutral, are either insoluble or difficultly soluble. Acids precipitate an insoluble acid antimonite from neutral solutions. The alkaline antimonites are formed by dissolving the hydrated acid, or by fusing the acid with caustic or carbonated alkali; the rest by double decomposition. The dry salts heated, generally give off crystal-water, become luminous before ignition, appearing to undergo combustion, and become lighter colored and more fixed compounds, which are decomposed by acids with difficulty. This is especially the case with antimonites of copper, cobalt, and zinc.

Antimonite of Potassa. Lat. *Stibii Kalicus*. Ger. *Antimonigsaures Kali*. Fuse antimonious acid with carbonated or caustic potassa, dissolve out the alkali and wash the residue several times with cold water; dissolve the remainder, which is the neutral salt, in boiling water. The solution, by evaporation, dries to yellowish gummy mass, soluble in water, with an alkaline and metallic taste. Acids, even the carbonic, precipitate an acid antimonite, which is decomposed by an excess of acid. Form. of the neutral salt, $\text{KO} + \text{SbO}_4$.

Antimonites of Soda and Ammonia are both soluble in water. The latter exposed to the air loses ammonia, and a white, pulverulent, acid antimonite remains.

Antimonite of Baryta. Prepared by double decomposition, as a white powder; obtained crystallized by adding, dropwise, a boiling dilute solution of antimonite of potassa to a boiling dilute solution of chloride of barium. It deposits flat, silvery needles, unchangeable in the air. Form., $\text{BaO} + \text{SbO}_4$.

Antimonites of Lime and Protoxide of Iron are white, insoluble; the latter becomes yellow in the air.

Antimonite of Cobalt, CoO, SbO_4 , a volumi-

nous powder, of a pale violet tint, slightly soluble in water. Heated, it loses its crystal-water, becoming black, then appears to undergo combustion, and becomes white.

Antimonite of Copper, CuO , SbO_3 , green, insoluble, less crystalline than the antimoniate. When heated, it acts like the preceding without becoming black.

Salts of Antimonic Acid.

It forms neutral and acid salts with the alkalis, the former soluble, the latter less so; all other salts are difficultly soluble or insoluble. The alkaline are formed by fusing antimony with an alkaline nitrate, the rest by double decomposition. The salts of antimonic acid exhibit a similar combustion with the corresponding salts of antimonious acid.

Antimoniate of Potassa. Syn. Lat. Stibias Kalicus. Ger. Antimonsaures Kali.

Prep. 1. Fuse caustic potassa and antimonic acid. 2. Project into a heated crucible, portionwise, a mixture of 1 pt. powdered antimony with 3—4 pts. saltpeter and 1 carbonate of potassa, keep it in fusion one hour; lixiviate the powdered mass with cold water, which extracts nitrate and carbonate of potassa, then boil with water, which dissolves the antimoniate and leaves a small quantity of binantimoniate, together with oxide of iron, lead, &c. By evaporation it yields granular crystals, little soluble in cold water; formula, according to Rammelsberg, KO , $\text{SbO}_3 + 5\text{HO}$; or it may be evaporated until, on cooling, it congeals to a white saline mass. When pure, the solution has a slight metallic taste and scarcely alkaline reaction. It is precipitated by acids (even the carbonic) as an acid or binantimoniate of potassa. KO , $2\text{SbO}_3 + 6\text{HO}$, Guibourt. The former officinal preparation, still employed to a limited extent, was made by deflagrating antimony or its sulphuret and saltpeter, dissolving out by cold, and the residue by boiling water, and precipitating the latter solution by sulphuric or muriatic acid. A better precipitant is carbonic or acetic acid. But the precipitated binantimoniate usually contains antimonious acid and oxide of antimony.

	H = 1	O = 100	In 100 pts.
KO	47.2	589.92	21.83
SbO_3	169.2	2112.90	78.17
	216.4	2702.82	100

Form., $\text{KO} + \text{SbO}_3$ ($\text{KO} + \text{Sb}_2\text{O}_3$, Berz.).

Use. Rarely employed in medicine, and latterly recommended by Fremy and by Wackenroder as a test for soda.

Antimoniate of Soda. Syn. Stibias Natricus, Antimons. Natron. Formed like the preceding, with caustic or nitrate of soda, or by adding antimoniate of potassa to a solution of soda, and shaking the liquid. In the latter case, microscopic crystals deposit belonging to the quadratic system, being 4-sided prisms, with terminal truncations. Wackenroder. Good crystals are best obtained from a solution containing an excess of caustic soda. Mitscherlich. It is nearly insoluble in water. Form., $\text{NaO} + \text{SbO}_3$ (Sb_2O_3 , Berz.).

Antimoniate of Ammonia. Digest hydrated antimonic acid with strong liquid ammonia. It is decomposed by evaporation, yielding the binantimoniate as a white powder, with acid reaction. Form., $\text{NH}_4\text{O} + \text{SbO}_3$.

Antim. of Baryta. Mix antimoniate of potassa and chloride of barium. A white, amorphous precipitate, slightly soluble in water, unaltered in air, and by carbonic acid. Form., $\text{BaO} + \text{SbO}_3$.

Antim. of Lime. Ger. Ant. Kalkerde. Mingle antim. of potassa and chloride of calcium. A white crystalline powder, very slightly soluble in water. Form., $\text{CaO} + \text{SbO}_3$. The antimonates of the earths are insoluble, white compounds.

Protantimon. of Manganese. Mingle antim. of potassa and protosulphate or chloride of manganese; the first portions of the precipitate redissolve. It is a white powder, unaltered in air, difficultly soluble in water; by ignition it becomes gray, by a higher heat white, and is then insoluble in acids.

Antimon. of Protoxide of Iron. Ger. Ant. Eisenoxydul. White precipitate becoming yellow in the air. The salt of peroxide is pale yellow, insoluble.

Antim. of Cobalt, formed by double decomposition with a hot cobalt-solution, redissolves at first, but subsequently deposits as a pale red crystalline powder, nearly insoluble in water. At a high temperature it loses crystal-water, becoming dark violet, nearly black; by ignition it exhibits a lively combustion, becoming white, with a faint reddish tint, and is insoluble in acids. Form., $\text{CoO} + \text{SbO}_3$.

Antim. of Nickel, greenish white, insoluble in water. Form., $\text{NiO} + \text{SbO}_3$.

Antim. of Zinc. When antim. of potassa is added to a neutral solution of zinc, the precipitate at first redissolves, but on adding more, it remains undissolved as a white powder; portions of it separate from the liquid in a few hours as minute crystals on the sides of the glass. When heated it exhibits the same phenomena as the salt of cobalt, and is not then reduced nor fused with alkali on charcoal before the blowpipe. Form., $\text{ZnO} + \text{SbO}_3$.

Antim. of Lead. Ger. Ant. Bleioxyd. Forms a white, caseous precipitate, by double decomposition; it is also formed by treating antimonuret of lead by nitric acid. Insoluble in water; by heat becomes yellow, is infusible, but reducible on charcoal by the blowpipe to antimonuret of lead. Decomposed imperfectly by acids, even when freshly precipitated. Form., $\text{PbO} + \text{SbO}_3$.

Antim. of Copper. Ant. Kupferoxyd. A green, insoluble, crystalline powder, losing 19.5 per cent. or between 5 and 6 eq. water by heat, and becoming black; at a higher heat it exhibits combustion like the salt of cobalt, and is then undecomposable by acids or alkalis in the humid way; it is easily reduced on charcoal before the blowpipe to a pale globule of copper.

Antim. of Red Oxide of Mercury. Formed by double decomposition in the humid way, it is an orange-yellow precipitate. It is also obtained by heating in a retort a mixture of 1 pt. powdered antimony and 6—8 pts. red oxide of mercury; mercury distils over, and the antimo-

niat of mercury remains of a dark olive-green color; like the salts of cobalt, zinc, &c., it is not decomposable by acids or alkalies in the humid way; it is slightly soluble in boiling chlorohydric acid, from which ammonia throws down a light-green precipitate. It is easily decomposed by a high heat into oxygen, mercury, and antimonious acid. Form., $\text{H}_2\text{O} + \text{SbO}_5$.

SULPHOSALTS.

There are three orders of sulphosalts of antimony, consisting of one of the three sulphurets of antimony united to a sulphobase. Of those containing the sulphuret, SbO_3 , termed hyposulphantimonites, few have been formed artificially, but several are found in the mineral kingdom. Of the sulphantimonites still less is known. The sulphantimonites have been latterly investigated by Rammelsberg. The sulphosalts of antimony, with alkaline base, are soluble in water, and crystallizable.

Hyposulphantimonites.

For the salts of sulphuret of antimony, combined with sulphuret of lead in different proportions, see *Zinckenite*, *Plagionite*, *Jamesonite*, *Feather-ore*, *Boulangerite*, *Geokronite*, and *Kilbrickenite*. For those containing sulphuret of silver, see *Miargyrite*, *Ruby Silver*, and *Brittle Silver*. *Berthierite* contains sulphuret of iron; *Antimonial Copper* and *Cupreous Antimony* contain sulphuret of copper, Cu_2S . More complex are *Bournonite*, *Gray Copper*, *Polybasite*, and *Kobellite*. The artificial salts are too little known to admit of description.

Sulphantimonites.

The sulphantimonites are prepared, according to Rammelsberg, 1. by combining a sulphobase or a sulphydrate with sulphantimonie acid; 2. decomposing an antimoniate by sulphuretted hydrogen; 3. dissolving sulphantimonie acid in caustic or carbonated alkali; 4. fusing an alkaline sulphuret with sulphuret of antimony, dissolving in water, and boiling with sulphur.

The salts with an alkaline or alkalino-earthly base are soluble in water, insoluble in alcohol; all others insoluble in both menstua. From the solutions of the former acids (even carbonic), precipitate sulphantimonie acid (golden sulphuret), while sulphuretted hydrogen escapes. Their general formula is $3\text{RS} + \text{SbS}_5$.

Sulphantimoniate of Potassium. Syn. *Sulfantimonias sesqui-kalicus*, *Kalium-Sulfantimoniat*, *Berz.* Prepared by fusing 18 sulphuret of antimony, SbS_3 , 15 carbonate of potassa, 13 caustic lime, and $3\frac{1}{2}$ sulphur, dissolving in boiling water, filtering, and crystallizing. It forms yellowish crystals, which deliquesce in moist air, and decompose on the surface. Their formula is $3\text{KS}, \text{SbS}_5 + 9\text{HO}$.

When sulphantimonie acid, SbO_5 , is dissolved in moderately strong caustic potassa, a white powder remains, $\text{KO}, 2\text{SbO}_5 + 6\text{HO}$; if the solution be evaporated, a colorless salt crystallizes out, not deliquescent, although decomposing superficially in the air. The same salt is obtained by the above process for sulphantimoniate, if the lime be omitted. It is a double salt of the above sulphantimoniate, with

antimoniate of potassa, and has the composition $3\text{KS}, \text{SbS}_5 + \text{KO}, \text{SbO}_5 + 10\text{HO}$. Cold water removes the sulphosalt and leaves the oxysalt; boiling water dissolves the whole without decomposition.

Sulphant. of Sodium. *Natrium-Sulfant.*, *Berz.* Obtained by igniting 4 pts. sulphuret of antimony, 8 pts. dry sulphate of soda, and 2 pts. charcoal, dissolving in hot water, and boiling the solution with 1 pt. sulphur; or by Mitscherlich's process given above under *Sulphantimonie acid*, omitting the precipitation by acid. Colorless crystals of the regular system, generally the hemioctahedron (tetrahedron) predominating; combinations are the right and left hemioctahedron, the same or one hemioctahedron, with the rhombic 12-hedron on the corners, or with the hemi-48-hedron, appearing with 6 planes on the corners. The salt is soluble in 2.9 water at 59° ; it fuses in its crystal-water by heat, loses it, but regains it in the air; apart from air it bears fusion at ignition, and dissolves again in water. Its solution gradually decomposes in air into carbonate and hyposulphite of soda and sulphuret of antimony; thus $2(3\text{NaS} + \text{SbS}_5) + \text{CO}_2 + 16\text{O} = \text{NaO}, \text{CO}_2 + 5(\text{NaO}, \text{S}_2\text{O}_2) + 2\text{SbS}_3$. Form. of the crystal, $3\text{NaS}, \text{SbS}_5 + 18\text{HO}$.

Sulphant. of Ammonium, prepared by dissolving SbS_5 in sulphydrate of ammonium. It is decomposed by evaporation and by alcohol; the dry salt is unknown.

The salt of *Barium* is prepared by dissolving SbS_5 in a solution of sulphuret of barium and precipitating with alcohol; it forms groups of radiated needles not deliquescent, but decomposed in the air. Form., $3\text{BaS}, \text{SbS}_5 + 6\text{HO}$.

The *Strontium*-salt is not crystallizable, alcohol precipitates it as an oily liquid. Form., $3\text{SrS} + \text{SbS}_5$.

The salt of *Calcium* is prepared like the barium-salt, and resembles the preceding.

The *Magnesium*-salt is prepared from sulphydrate of magnes. and SbS_5 ; is yellow, deliquescent, does not crystallize, and is decomposed by alcohol.

The metallic salts are prepared by adding a metallic solution to a solution of the above sodium-salt, and not by the reverse process.

The protosalt of *Manganese* is reddish brown, somewhat soluble; that of *Iron* black, and decomposed easily by the air. The salts of *Cobalt* and *Nickel* are black precipitates.

The salt of *Zinc* is dark orange, and somewhat soluble. By precipitating sulphate of zinc with the sodium sulpho-salt, a similarly colored precipitate is produced, consisting of $\text{ZnS}, \text{SbS}_5 + \text{ZnO}$.

The *Cadmium*-salt is orange-red; the protosalt yellowish brown; the salt of *Bismuth* dark-brown; that of *Uranium* yellowish brown.

The *Lead*-salt, $3\text{PbS}, \text{SbS}_5$, is dark-brown; potassa extracts the sulphantimonie acid and leaves sulphuret of lead; by heat it loses sulphur and becomes $3\text{PbS}, \text{SbS}_3$, which is artificial Boulangerite. The *Copper*-salt is dark-brown.

The salt of *Mercury*, $3\text{Hg}_2\text{S}, \text{SbS}_5$, is black. The salt from red oxide of mercury, $3\text{HgS}, \text{SbS}_5$, is orange-colored, becoming brown by drying. By digesting while still moist with

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chloride of mercury, or by adding the sodium sulphosalt to a solution of the chloride, a white compound is formed of the sulphantimoniate with oxychloride of mercury, = $3 \text{ HgS}, \text{SbS}_5 + 3 \text{ HgCl} + 3 \text{ HgO}$.

The Silver-salt, $3 \text{ AgS}, \text{SbS}_5$, is blackish brown and wholly insoluble. Ignited in close vessels, sulphur sublimes, and there remains $3 \text{ AgS}, \text{SbS}_5$, which is artificial Ruby-silver. *Rammelsberg in Pogg. An.* lii. 193—242.

ANTRIMOLITE. *Min.* A hydrated silicate of alumina and alkali, found at Bengane, Antrim, Ireland, and analyzed by Thomson. It fuses before the blowpipe to a white enamel without effervescence. Decomposed by chlorohydric acid, with the separation of gelatinous silica.

Analysis. SiO_3 43.47 + Al_2O_3 30.26 + CaO 7.5 + KO 4.1 + FeO 0.19 + Cl 0.098 + HO 15.32 = 100.938. It is difficult to construct a probable formula from the analysis, but it resembles Mesotype. *Rammelsberg.*

APATITE. *Min.* (*apatia*, to deceive). Syn. Phosphate of lime, Asparagus-stone, Moroxite, Chrysolite, Rhombohedral Fluor-Haloide (*Mohs*). *Ger.* Spargelstein. *Fr.* Chaux phosphatée.

Descrip. Cryst.; hexagonal system, usually the hexagonal prism terminated by the 6-sided pyramid and terminal plane; combinations are 2 hexag. prisms, and several hexag. pyramids on each prism; prism on main pyramid = $130^\circ 12'$, term. plane on 1st pyramid = $157^\circ 6'$, on 2d or main pyram. = $130^\circ 12'$, on 3d pyrm. =

	1.	2.	3.	4.	5.	6.
Lime	54.75	55.300	55.890	55.575	55.870	55.66
Chlorohydric acid	2.10	0.434	0.393	0.073	0.049	0.02
Phosphoric, fluohydric } acid and loss. }	43.15	44.266	43.717	44.352	44.081	44.32
	100	100	100	100	100	100

The apatites consist of 3 eq. basic phosphate of lime with 1 eq. of chloride or fluoride of calcium, or both, and their formulæ are

Chloric apatite = $\text{CaCl} + 3 (3 \text{ CaO}, \text{PO}_5)$.

Fluoric apatite = $\text{CaF} + 3 (3 \text{ CaO}, \text{PO}_5)$.

or $\text{Ca} \left\{ \begin{array}{l} \text{Cl} \\ \text{F} \end{array} \right. + 3 (3 \text{ CaO}, \text{PO}_5)$.

The apatite from Snarum (1) would therefore consist of

Chloric apatite.....	40.30
Fluoric apatite.....	59.70
	100

Localities. It is mostly found in primary rocks, and in some abundance. Fine pink crystals occur at Ehrenfriedersdorf, Saxony; the bluish green, called *Moroxite*, at Arendal, Norway, at Bolton, Massachusetts, and Wilmington, Delaware, United States. The most celebrated locality of apatite in the United States is at Gouverneur, St. Lawrence county, New York, where crystals have been found 6 inches in length and $1\frac{1}{2}$ in diameter; other localities are Amity, Greenfield, Green Pond and Anthony's Nose, in the Highlands, New York, Germantown, near Philadelphia, of a light

APHANESITE.

$120^\circ 36'$. The edges often rounded by partial fusion. Cleavage imperfect parallel to main prism and terminal plane. Crystalline; globular, reniform, fibrous, granular, the last called also phosphorite. $\text{H.} = 5$. $\text{G.} = 3.1 - 3.235$.

Prevailing color green, also bluish, yellow, brown, red, gray, white; vitreous; translucent, rarely transparent—opaque; streak white; fracture subconchoidal; brittle; some crystals phosphoresce by heat; others are electric by friction.

Behavior. Fuses with great difficulty in extremely thin pieces to a colorless, transparent glass; soluble in borax to a clear glass, that may be flamed milk-white; mic. salt dissolves more, and when nearly saturated, clouds on cooling, and exhibits facets; when saturated it is milk-white without facets; with soda, it swells with intumescence, the soda enters the charcoal and leaves a white mass; dissolved with difficulty by boracic acid, exhibiting phosphoric reaction with iron-wire; moistened with sulphuric acid, it tinges the blowpipe flame greenish. The powder is wholly soluble in chlorohydric or nitric acid; heated with sulphuric acid in a platinum crucible, it evolves fluohydric acid.

Analysis of 6 specimens by G. Rose, 1. from Snarum, Norway, not crystal., G. at $46.5^\circ = 3.174$; 2. from Capo de Gata, Spain, crystal., G. at $46.5^\circ = 3.235$; 3. Arendal, Norway, grass-green, $\text{G.} = 3.222$; 4. Greiner, massive, $\text{G.} = 3.175$; 5. Faldigl, crystal., G. at $63^\circ = 3.166$; and, 6. Gotthard, Tyrol, crystal., G. at $62^\circ = 3.197$.

green and transparent, Chester county, Pennsylvania, near Wilmington, Delaware, &c. Breithaupt's *Pseudo-Apatite* is probably apatite.

Use. Finely pulverized, it may be employed for the soil or for preparing phosphorus and its compounds.

APHANESITE. *Min.* (*αφανης*, not manifest). Syn. Diatomous Habroneme-Malachite, *Mohs*; Radiated acicular Olivenite, *Jam.* Strahlerz. *Hoffm.* Oblique prismatic Arseniate of Copper.

Descrip. Cryst. doubly oblique rhombic; P on $\text{M} = 85^\circ$ and 95° , M on $\text{M} = 56^\circ$ and 124° ; very minute crystals, with combinations of x, y , &c., and cleavage perfect parallel to P .

$\text{H.} = 2.5 - 3.0$. $\text{G.} = 4.192$.

Color and streak verdigris green, often externally black, internally bluish green, sometimes dark-blue; lustre pearly on P ; transparent, subtranslucent; sub-brittle.

Behavior, &c. Deflagrates, fusing readily, and emitting arsenical vapors. According to Chenevix it contains CuO , $22.5 + \text{Fe}_2\text{O}_3$ $27.5 + \text{AsO}_5$ $33.5 + \text{SiO}_3$ $3.0 + \text{HO}$ $12.0 = 98.5$. Found in Cornwall with other similar minerals. See **CUPREOUS ARSENIATES** and **PHOSPHATES**. Richardson's analysis places this mineral with **OLIVENITE**.

APHLOGISTIC LAMP. A lamp without flame, first contrived by Sir H. Davy. It may be made by coiling fine platinum wire around the wick of a spirit-lamp or a piece of camphor, inflaming it and blowing it out after the lapse of a few moments, by a sudden puff of air. The heated metal causes the vapors still rising, to enter into a *low combustion*, which maintains the ignition of the metal, until the combustible is consumed. The heat is not sufficient to cause it to burst into a flame; and the products of low combustion are usually different from the ultimate products of complete combustion, carbonic acid and water. See **COMBUSTION**, **FLAME**, and **HEAT**.

APHRITE. *Min.* See **CALCAREOUS SPAR**.

APHRIZITE. *Min.* See **TURMALINE**.

APHRODITE. *Min.* (*apoc, foam*). A species of Meerschaum found at Langbanshyttan, Sweden, closely resembling Meerschaum in its external characters. Berlin's analysis gives

Silica.....	51.55	51.58
Protox. of manganese	1.62	1.49
Protox. of iron.....	0.59	0.55
Magnesia.....	33.72	34.07
Alumina.....	0.20	0.13
Water.....	12.32	11.34
	100.00	99.16

It is therefore a hydrous silicate of magnesia, with the formula, $4(3\text{MgO} + 2\text{SiO}_3) + 3\text{HO}$. *Berz. Jahresb.* xxi. 170.

APHTHALITE. *Min.* See **SULPHATE OF POTASSA**.

APIRIN. *Chem.* A base supposed by Bizio to exist in the fruit of *Cocos lapidea*. Obtained by extracting with water and muriatic acid and precipitating by ammonia. It is white, resembling starch, inodorous and tasteless, producing a pungency after some time, soluble in

	1.	2.	3.	4.	5.	6.	7.
Silica.....	53.90	51.856	51.864	52.13	51.008	52.38	50.76
Lime.....	25.00	25.224	25.199	24.71	26.236	24.98	22.39
Potassa.....	6.13	5.307	5.137	5.27	5.888	5.37	4.18
Fluohydric acid..	—	—	—	0.82	—	0.64	trace
Water.....	15.70	16.905	16.044	16.20	16.500	16.20	17.36
	100.73	19.292	98.244	99.13	99.632	99.57	94.69

Berzelius writes the formula, after abstracting fluohydric acid, $\text{KO}, 2\text{SiO}_3 + 8(\text{CaO}, \text{SiO}_3) + 16\text{HO}$; but if the fluorine be abstracted as silico-fluoride of calcium, which, in that from Utön amounts to 4.82 per cent., and that from Faröe to 3.53 per cent.; the formula might be $\frac{3\text{CaO}}{3\text{KO}} \frac{2}{5} 4\text{SiO}_3 + 6\text{HO}$. *Ram.*

Localities. Besides the above, it occurs also at Andreasberg in silver veins; in the Bannat; Puy de la Piquette, Auvergne, in limestone; Werner's white, opake *Albin*, at Aussig, Bohemia; *Oxhaverite*, pale green, on petrified wood, from Oxhaver Springs, Iceland; Brewster's *Tesselite*, from Nalsöe, Faröe Islands, nearly cubical, exhibiting, upon optical examination, a tessellated structure.

APOSEPIDIN. See **CASEIN**.

APOTHEM. *Phar.* When a watery infu-

600 pts. cold water, has not alkaline reaction; the solution clouds by heating and becomes clear on cooling; soluble in acids; precipitated by basic acetate of lead, not by tannic acid. *Berz.*

APLOME. *Min.* See **GARNET**.

APOPHYLLITE. *Min.* (*apoc, off, φυλλον, leaf*). Syn. Ichthyophthalmite, Fischaugenstein, *Albin, W.*; Pyramidal Kouphonespar, *M.*; Pyram. Zeolite, *Jam.*; Tesselite, *Brews.*; Mesotype epointée, *H.*

Descrip. Cryst. Quadratic; the octahedron, with the terminal plane and a square prism of 2d order; the term. planes often so large as to make tabular crystals; adjacent planes of octahedron, o on $o = 104^\circ 18'$, terminal planes P on $o = 120^\circ 5'$, 2d prism M on $o = 128^\circ 20'$. Cleavage very perfect parallel to P , nearly as perfect parallel to M . Sometimes crystalline, of a lamellar structure.

$H. = 4.5 - 5.0$. $G. = 2.3 - 2.5$.

Color white, gray with reddish, greenish, or yellowish tints; lustre on P pearly, on other planes vitreous; transparent—opaque; brittle, with uneven fracture.

Behavior. Gives much water in a tube, becomes dull by heat, swelling in the direction of its laminæ, and fuses with intumescence to a white vesicular enamel; dissolves easily in borax, the saturated bead can be flamed white; leaves a skeleton of silica in mic. salt; forms a clear bead with soda; strongly heated in a tube, it tests of fluohydric acid. It exfoliates in muriatic acid, forming a pasty mass without gelatinizing; unchanged by acid after ignition.

Analyses of apoph. from Disco Eiland, Greenland, 1. by C. Gmelin, and, 2. by Stromeyer; 3. from Fassa, Tyrol, by Stromeyer; from Utön, Sweden, 4. by Berzelius, 5. by Thomson; 6. from Faröe Islands by Berz.; 7. var. *Oxhaverite* by Turner.

sion or decoction of a dried plant or the expressed juice of a fresh plant is evaporated to the consistence of extract, and water is again added, a brown powder separates, which has been termed *oxidized extractive* matter, but incorrectly; and hence Berzelius denotes it by *Apothem* (*ἀπό, from, θέμα, deposit*), or extract-deposit. It is slightly soluble in water, coloring it yellowish or reddish, and depositing again by evaporation; more soluble in alcohol, much more in hot alcohol; very soluble caustic alkali forming a dark brown solution, when concentrated; soluble in carbonated alkali, from which acids precipitate it, combined with some of the acid. See **EXTRACT, HUMIN, ULMIN**.

APPARATUS. *Chem. Phys.* A combination of several things arranged for experiment, in order to exhibit the phenomena of chemistry or physics, or to determine their laws.

APPLE.

APPLE. *Bot.* The fruit of the *Pyrus Malus*. It has the same composition as the pear. See *PYRUS*.

AQUA. The Latin word for water. It is often abbreviated in chemical formulæ, and written *aq.* instead of *HO*, especially to express crystal-water.

AQUA FORTIS. Signifying *strong water*. A term formerly applied to nitric acid, and still used in the arts. See *NITRIC ACID*.

AQUA REGIA, or *Royal-water*. A mixture of nitric and muriatic acids, employed by the alchemists to dissolve the king of metals, gold, whence its name. See *CHLOROHYDRIC* and *NITRIC* acids.

AQUEOUS. Containing or produced by water; thus, an aqueous solution or infusion is one in which water is the solvent.

ARABIN. *Chem.* A name for that kind of gum which constitutes the principal part of Arabian gum. See *GUM*.

ARCHIL. *Tech.* See *ORCHIL*, *CUDBEAR*, *LITMUS*, and *LICHENS*.

ARCTOSTAPHYLOS and **ARBUTUS.** See *BEARBERRY*.

ARENDALITE. *Min.* See *EPIDOTE*.

AREOMETER. *Tech.* See *HYDROMETER*.

ARFWEDSONITE. *Min.* See *HORNBLÉNDE*.

ARGAL or **ARGOL.** *Tech.* A name for the crude bitartrate of potassa deposited in wine-casks. See *TARTARIC ACID* and *TARTRATES*.

ARGILLACEOUS.

ARGENTAN. *Tech.* An alloy composed of copper, nickel, and zinc, which has been made and employed for a long time in China under the name of *Pack-fong* (white copper), and within the last half century has been largely manufactured in Europe. *Syn.* *Pack-fong.* *Ger.* *Argentan*, *Neusilber*, *Weisskupfer*. *Fr.* *Cuivre blanc*, *Maillechort*. *Engl.* *Argentan*, *German Silver*, *British Plate*.

An alloy of copper and nickel may be made as white as silver, but nickel being an expensive metal, a portion of it is replaced by zinc without a diminution of the whiteness of the metal. In fusing the three metals together, there is always a loss of zinc by volatilization, which may be lessened by placing the zinc below the copper in the crucible, or by thrusting the zinc under the melted copper, or lastly, by first melting the zinc at a low temperature, and gradually introducing strips of copper to form a kind of brass, which is then broken, mingled with the balance of the copper and nickel, and melted.

The qualities and adaptation of argentan vary with the proportion of the metals and purity of the nickel. If the latter contain arsenic, the argentan will be more or less brittle; only pure nickel should therefore be employed. The following table exhibits the composition of argentan:

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Copper	88	43.8	40.4	53.4	50.0	65.0	50	55	60	57
Nickel	8.75	15.6	31.6	17.5	18.7	16.8	25	20	20	20
Zinc	—	40.6	25.4	29.1	31.3	13.0	25	25	20	20
Iron	1.75	—	2.6	—	—	3.4	—	—	—	lead 3
	98.5	100	100	100	100	98.2	100	100	100	100

The first 6 are the results of analysis. No. 1 is the Suhl white copper, made a century since at Suhl, in Germany, and analyzed by Brandes; 2 and 3 are Chinese *Pack-fong*, 2 analyzed by Engström in 1776, and 3 by Fyfe, who detected the iron in it in 1821. This specimen, 3, was very similar to silver, took a high polish, was highly sonorous, could be hammered, rolled, and drawn at ordinary temperatures; spec. grav. = 8.432 at 54.5°. Nos. 4 and 5 are the results of Frick's experiments; the metal was very like 18 carat (75 per cent.) silver, but harder, very tough, ductile, becoming softer by quenching. Spec. grav. = 8.556 at 67°. No. 6 is Maillechort, made at Paris; it laminates well, receives a fine polish or gilding; spec. grav. 7.18; it loses 12 per cent. at a high heat, becoming much whiter. *Berthier*. Nos. 7—10 are the proportions given by Gersdorff of Vienna, 7 is adapted to forks, &c.; 8 for decoration of knife-handles, &c.; 9 for rolling; 10 for objects which require soldering, such as lamps, &c.

It will be observed that the composition, as above given, varies, and an alloy, similar in appearance, may be made with less than 10 per cent. nickel; but the wearing quality of the metal is decidedly injured by too great a reduction in the quantity of nickel. During the operations of hammering and rolling, the tenacity of the metal is injured and must be

restored by reheating, which should be done carefully, not beyond a low red heat, in order to avoid the formation of oxide on the surface. A small amount of iron or steel added, some 2—3 per cent., increases considerably the whiteness of the metal, but renders it harder and more brittle.

As German silver is frequently used as spoons, forks, and other domestic utensils, some cautions may be given with propriety. An experiment made with No. 5, by treating it with acetic acid, proved that it lost about one grain more than silver-plate containing 75 per cent. silver; it behaved similarly to olive oil and butter. The trace of arsenic it may contain is of no account. It should not be used in vinegar or with acid fruits, and its surface should always be kept clean and bright. It is far less likely to prove injurious than vessels of copper, brass, or bell-metal, for which it may be substituted with advantage. See *ALLOYS*, *NICKEL*.

ARGENTIFEROUS GOLD. *Min.* See *GOLD*.

ARGENTINE. *Min.* See *CALCAREOUS SPAR*.

ARGILLACEOUS. *Geol.* Containing clay, clayey. Applied chiefly to slates, sometimes to sandstone-formations. The appearance of a geological specimen often indicates the presence of clay. It may be also determined by breathing on the specimen, which emits an *argillaceous odor*.

ARGILLITE. *Geol.* See CLAY-SLATE.

ARICIN. A vegetable base, discovered by Pelletier and Carriol in the bark known as China de Cusco or Arica bark, from which it is obtained in the same way as quinin and cinchonin from the other barks. This bark is often fraudulently mingled with the others. Guibourt considers the Cusco to be identical with the Arica bark, but the only alkaloid he obtained from it was cinchonin, about one drachm from a pound.

Aricin crystallizes in shining, white, transparent needles, tasteless at first, subsequently bitter, astringent, unalterable in air; fuses readily, decomposed before it volatilizes; insoluble in water, more soluble in alcohol than cinchonin, soluble in ether; colored green by strong nitric acid, combines with the dilute. Pelletier's analysis leads to the formula, $C_{20}H_{12}NO_3$, which, he observes, makes it the tritoxide of the same radical as exists in quinin and cinchonin; it requires re-examination.

The salts of aricin have a bitter taste, are soluble in water and alcohol, but not in ether. The neutral sulphate, by concentration and cooling, forms a jelly, by evaporation to dryness, a translucent horny mass; it crystallizes from a hot saturated solution in alcohol. The bisulphate crystallizes in needles. The action of aricin on the system has not been determined. See QUININ.

ARISTOLOCHIA. *Phar.* See SNAKE-ROOT.

ARMORACIA. *Phar.* See HORSE RADISH.

ARNICA. *Phar.* The *Arnica montana* (Ger. Wolverley) of the tribe Senecionidæ, order Compositeæ, inhabits the cooler portions of Europe. The root yielded to Pfaff:

Volatile oil.....	1.5
Acrid resin.....	6.0
Extractive.....	32.0
Gum.....	9.0
Fibre.....	51.5
	100

Weber's analyses of the flowers, gave

Acrid resin.....	7.5
Extractive (with malic acid and acetates).....	15
Brownish gray resin (with malates and acetates).....	17.5
Insoluble in alcohol.....	60
	100

Besides the above, Lassaigne and Feneulle detected in the flowers, a yellow coloring matter, albumen and gallic acid. The leaves of the plant contain principles similar to the above, but less of the resin.

The vol. oil of the root is yellowish, lighter than water, of an aromatic burning taste. The vol. oil of the flowers is blue, *Martini*. The acrid resin, called *Arnicin*, appears to be the active principle; from the flowers it is greenish yellow, from the root green or brownish, soluble in alcohol with the same color, of a burning, bitter taste. The extractive is, according to Lassaigne, bitter, acrid, nauseous, soluble in

water and alcohol; analogous to Cytisin. It is employed, but rarely, in Pharmacy.

ARNOTTO. *Tech.* Syn. Anatto, Terra Orellana. *Fr.* Roucou. *Ger.* Orlean. A doughy, odorous colouring matter derived from the seed pulp of *Bixa Orellana*, a native of the West Indies.

Prep. The seeds, surrounded by the colored pulp, are kneaded under warm water, the liquid passed through fine sieves, evaporated to a stiff paste, and dried in the shade. It is sold in the form of cakes, brown without, of a fire-color within. John's analysis gave 28 resin, with coloring matter, 20 colored extractive, 26 gum, 20 fibre, with free acid and an aromatic substance. The coloring matter is slightly soluble in water with a yellow color; much more in alcohol with orange yellow; still more in ether with a red color. Caustic alkali extracts the color of a dark orange when strong, and acids precipitate it again orange-yellow. Oil of vitriol colors arnotto first blue, then green, lastly violet. Cold nitric acid poured over it produces no change; with a little acid it becomes syrupy and explodes by a gentle heat. Chevreul found two coloring matters in it, a yellow, soluble in water, alcohol, and slightly in ether, a red, soluble in alcohol, ether, and slightly in water. A decoction of arnotto produces in solutions of alum and coperas an orange-yellow precipitate, in sulphate of copper a brownish yellow, in tin-salt a lemon-yellow.

Use. It was formerly used for imparting an orange color to wool, cotton, and silk, but is now almost exclusively confined to silk-dyeing. For this purpose it is dissolved by boiling in water with its own weight of pearlash or less of soda-ash. The scoured silks are immersed in a bath of luke-warm water, to which the alkaline solution of arnotto is added according to the depth of shade required, and when the color is full they are washed to remove the excess of arnotto. As the alkali graduates the color more into yellow, an orange is attained by using a solution made with less alkali than that above given, or by dyeing as above, and then brightening by passing through alum, vinegar, or lime-juice; the acid, by neutralizing the alkali, restores the original reddish hue. For a more red tint, pass through a weak bath of Brazil-wood. The colors from arnotto are brilliant but fugitive.

It is farther employed to impart a faint orange tint to cheese, at the rate of one ounce or less to a cwt.; for tinting butter; to color varnishes, fixed or volatile oils, tinctures, &c. The average importation into England in 1834—5 was 200,000 lb.

AROMA (*αρωμα, spice*). Aromatic substances generally owe their peculiar odor to volatile oils which they contain. See ESSENTIAL OILS.

ARRACK. *Tech.* This term is applied in general to spirituous liquids in India and the adjacent Islands, but specially denotes the distilled liquid from Toddy. The latter is a liquid obtained by incision from the upper part of Cocoa-nut tree, *Cocos nucifera*. Goa and Columbo arrack is always made from toddy; Batavia and Jamaica arrack from molasses and

ARRAGONITE.

rice, with some toddy. The Pariah-arrack is also said to contain *Cannabis sativa* and a species of *Datura*, which render it more intoxicating and pernicious, but the term may only designate an inferior spirit. A very large amount of arrack is consumed in the East; 6—700,000 galls. are annually exported from Ceylon, and some 30,000 imported into England.

ARRAGONITE. *Min.* Syn. Prismatic Lime-Haloide, *Mohs*; Needle-Spar, Flos-ferri, Igloite, Eisenblüthe, *Wern.*

Descrip. Cryst. Right rhombic; usually the vertical prism = $116^{\circ}10'$, with large terminal plane of a lateral axis, and terminated with one or more 8-hedra and horizontal prisms, and sometimes the terminal plane of main axis. Macled crystals are frequently found consisting of 2 or more crossing each other, sometimes distinct, but often the re-entering angles filled, exhibiting their union only by striæ on the sur-

face meeting at an angle; in such combinations, the predominating form of each crystal is the vertical prism with large lateral terminal planes. Cleavage parallel to vertical prism. It occurs also in straight or divergent columns and fibres. The flos-ferri is a coralloidal form of fine fibrous and granular structure.

H. = 3.5—4.0. G. = 2.931, *Mohs*, 2.995, *Breith.*

Color white, sometimes yellowish, grayish, greenish, bluish; lustre vitreous; transparent, translucent; double refraction feeble; brittle, subconchoidal fracture; streak white.

Behavior. Similar to that of calcareous spar, except that it phosphoresces on red-hot iron, and by a heat below ignition it loses a little water, falling to a light, fluorescent powder, which, under the microscope, proves to be of the form of calcareous spar. Rarely gives traces of oxide of lead.

Analysis. 1—5 by Stromeyer, 6 by Büttger:

	1.	2.	3.	4.	5.	6.
Carbonate of lime	97.096	97.983	97.184	98.000	98.946	95.940
Carbonate of strontia . .	2.461	1.093	2.239	1.014	0.507	PbO, CO ₂ = 3.859
Hydrated perox. of iron .	—	—	0.221	0.145	0.143	—
Water	0.410	0.258	0.308	0.214	0.198	0.157
	99.967	99.334	99.952	99.373	99.794	99.956

It has been shown that the form of arragonite can be obtained artificially, without the presence of strontia or any other isomorphic base, and hence its formula is the same as that of calcareous spar, $\text{CaO} + \text{CO}_2$.

Local. It occurs frequently in basaltic rocks; associated with gypsum as in Arragon, Spain, whence the name; in beds of iron-ore, called hence flos-ferri. Found in many localities in the United States.

ARROW-ROOT. *Tech.* A form of starch derived from the tubers of the root of the *Maranta arundinacea*.

Benzon's analysis of the root gives:

Volatile oil	0.07
Starch	26.00
Albumen	1.58
Gummy extract	0.50
Chloride of calcium	0.25
Insoluble fibre	6.00
Water	65.60
	100.00

To prepare the starch the tubers of a year old are washed, stamped in wooden mortars to a pulp, thrown into a tub of water, the fibrous parts removed, the liquid passed through a hair-sieve, suffered to settle, and the clear water run off. The sediment is again washed with water, and after settling, dried in the sun. It is sometimes adulterated with potato-starch, or the latter is wholly substituted for it, but they may be distinguished by a good microscope. See *Pereira's Mat. Med.* It is employed as an article of food, or as a nutritious, easily-digested diet for invalids and infants. The quantity imported into England annually rises above 100 tons. For its composition and chemical behavior, see **STARCH**.

ARSENIC.

ARSENIC. Sometimes improperly termed Cobalt. Syn. Arsenicum. *Ger.* Arsenic, Fliegenstein. *Fr.* Arsenic, Pierre à mouches.

Sym. As. Equiv. 75.3 (or 940.08 when O = 100. Berzelius and others take the atom of arsenic to be $\frac{1}{2}$ the above, = 37.6 or 470.04).

Some of the compounds of this metal were known to the ancients; Hippocrates employed 'Ἀρσενικόν (*Orpiment*), and Σηδηρενικόν (*Realgar*); Dioscorides mentions 'Ἀρσενικόν (*Orpiment*). The Arabian Geber, 8th century, mentions White Arsenic (arsenious acid), and may have known the metal. Brandt obtained the metal in 1773. It enters, as an important agent, into many branches of the arts, although the quantities employed are comparatively limited; and it is chiefly used as arsenious acid, sulphuret, and in the metallic state.

METALLURGIC TREATMENT OF ARSENICAL ORES.

Arseniurets of iron and other metals are rather abundant, and yield arsenious acid by calcination. Hence it is often a secondary product in treating the ores of several metals, such as those of tin, cobalt, and nickel; but arsenical iron-ores are sometimes employed solely for obtaining the acid or metallic arsenic. The latter is the case at Altenberg and Reichenstein in Silesia, where the operations are calcination and refining.

Calcination. Pl. III. figs. 6, 7, 8, represent the arsenical furnace of Altenberg; fig. 6 a vertical section of the condensing chambers (Giftthurm, Giftfang), with an outline of the adjoining furnace; fig. 7, a section of the muffel-furnace; fig. 8, a cross section of the same. *a* is the muffel, *b* the opening for stirring the charge, *c c c* flues through which the fire and smoke pass into the escape-flue *e*; *d* is the opening for charging the muffel with shliech (schliech, prepared ore), *f* two flues for the exit of the

arsenical fumes, which pass into two others *g*, unite in one at *h*, pass into the vault *B*, from this through the door *i* into the gallery *k*, from the farther end of which they pass by a door, *l*, successively through the condensing chambers *m*, *n*, *o*, *p*, *q*, *r*, *s*, and the uncondensed gases escape at *s*. The covers, *t*, are removed at the close of the operations to throw the condensed material into the lower chambers.

The muffel is charged with 9—10 cwt. shliech through *d* (which is then closed), and spread upon the inclined hearth through *b*, to the depth of 2—3 inches. A rapid fire is given to a red-heat, followed by a lower temperature, which is maintained, until after some 12 hours the exhausted shliech is raked out. The front of the furnace being kept open, the air enters and passes through in consequence of the heat and inclination of the muffel, oxidizing the metals exposed on the hearth; and in order to complete the oxidation throughout, the shliech is repeatedly raked.

Sulphurous acid and air pass out through *s*; arsenious acid condenses in the various flues and chambers, the purest collecting in the lower chambers, while the upper contain sulphur. The oxidation of the materials undoubtedly assists in heating, and hence the small consumption of fuel, amounting to $4\frac{1}{2}$ bshl. per charge. Every 8 or 10 weeks the product, some 25 tons, is removed from the chambers. The crude product, consisting mainly of arsenious acid, is generally refined to make the commercial article.

Refining. Pl. III. figs. 9 and 10 exhibit the refining furnace at Reichenstein. Fig. 9 represents in A a vertical section, in B a front view; fig. 10 a plan of the 4 fireplaces. *a* the grates, *b* the ash-pits, *c* the fire-doors, *d* the fireplace, *e* iron kettles charged with the crude acid, *f* fire-flues conducting to the chimney *g*, *h* iron drums, *i* caps, *k* tubes leading to the condenser *l*, *m* openings to introduce probing wires.

The kettle is nearly filled with $3\frac{1}{2}$ cwt. crude acid, the drums fastened on by a lute of loam, blood, and hair, and gently heated at first, which in a $\frac{1}{2}$ hour is increased. The acid vapors rise and condense on the cylinders as a white dust or crystals, which, by continued firing, cement into a transparent layer, of 2 inches thickness, *arsenical glass*, $\frac{1}{3}$ of which is white, the upper part brownish. The latter is subjected to one or more resublimations to get it pure. See *Arsenious Acid* below, COBALT, TIN.

Metallic Arsenic is prepared by subjecting native arsenic or arsenical iron to sublimation in earthenware retorts, with receivers attached, in which is generally introduced a piece of sheet iron rolled up to collect the greater portion of the sublimate. Another method is to reduce arsenious acid by mingling the brown arsenical glass with charcoal or black flux and subliming. See *Arsenic*, below.

Realgar is prepared from ores of arsenical iron, containing much iron pyrites, by filling earthen retorts $\frac{3}{4}$ full of the shliech, giving a gentle heat for $1\frac{1}{2}$ —2 hours, which is gradually increased to redness and maintained so for 8—10 hours. The earthen recipient contains red arsenical powder, which is added to a fresh charge, and red arsenical glass, which is

refined. For this purpose some 20 to 25 lb. are fused in cast-iron kettles (or sheet-iron cylinders) under a chimney with good draft; the slags drawn off, the realgar tested by taking out a little on a test-iron; if too dark, sulphur is added, if too light, a darker realgar; it is then cast in cylinders of sheet-iron.

Orpiment is also prepared in the refining kettles, with sheet-iron cylinders, for arsenious acid, as described above. The directions are to introduce a mixture of 7 pts. arsenious acid and 1 pt. roll-sulphur, and give a gradually increasing heat which develops sulphurous acid and sublimes orpiment. (?) The inferior kind is added to a fresh charge. It usually contains quantities of arsenious acid, which had not been reduced. It may be observed that to reduce arsenious acid, according to the formula, 1 eq. of acid requires $4\frac{1}{2}$ eq. sulphur to form orpiment and burn off the oxygen; 10 pts. of acid would therefore require about 7 pts. sulphur, a proportion very different from that stated above. To convert realgar into orpiment, 7 pts. require 1 of sulphur, so that in the above directions for making orpiment, the 7 pts. arsenious acid should read 7 pts. realgar or red arsenical glass. There was, however, an orpiment made according to those directions, which consisted, according to Guibourt, of 94 per cent. arsenious acid and 6 per cent. sulphuret of arsenic.

ARSENIC AND ITS METALLOIDAL COMBINATIONS.

Arsenic. Prepared impure, see above. It may be easily prepared on a small scale by subliming in a glass retort a mixture of arsenious acid and charcoal or oil; or 1 pt. of the acid and 3 pts. black flux, in a crucible, with another inverted over it as a cover; the latter being kept cool, the metal condenses on its inner surface.

Prop. The condensed vapor crystallizes in irregular rhombohedra, like antimony. Metallic arsenic has a steel-gray color, brilliant metallic lustre, is brittle; spec. grav. = 5.7, or heated to ignition = 5.96. *Guibourt.* It vaporizes at 356° without previous fusion; spec. grav. of vapor = 10362; the vapor, in contact with air, has a peculiar odor, resembling phosphorus or garlic, by which its presence is often recognised. Its surface tarnishes in the air with a dull grayish black coating of suboxide; it deflagrates violently when heated with saltpeter, and explodes by a stroke with chlorate of potassa. It burns when heated in oxygen, spontaneously in chlorine, with a brilliant, white light, and is converted into arsenious acid. Its use is very limited, being confined chiefly to alloys, with lead and copper, which see below. It unites readily with most metals, rendering the malleable more brittle; those difficult of fusion more fusible; and the colored whiter. It is difficult to remove it wholly by calcination.

1. *Suboxide of Arsenic.* Syn. Flypowder. Metallic arsenic usually becomes coated with a black layer of suboxide, and sometimes the whole falls to a black powder. It separates by heat or acids into arsenious acid and metallic arsenic.

2. *Arsenious Acid.* Syn. Arsenic, White Arsenic, Oxide of Arsenic, Ratsbane; Acidum

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arsenicum. *Ger.* Arsenige Säure, Giftmehl, Hüttenrauch, Rattenpulver, Arsenik.

It occurs native (see ARSENIOUS ACID), but is prepared either as a principal or secondary product by the calcination of arsenical ores (see above). The commercial article is white, transparent, and glassy when fresh, becoming milky and opaque by exposure, so that the two states are usually observed on breaking a mass which is opaque on the exterior. Rose's investigations seem to prove that these are two allotropic or dimorphic states of the acid, possessing different properties. The transparent or vitreous has a spec. grav. of 3·739 and 9·68 pts. are soluble in 100 pts. boiling water, and the solution reddens litmus-paper; the opaque has a spec. grav. of 3·699 and 11·74 pts. are dissolved by 100 boiling water, and its solution faintly blues litmus, which had been reddened by acids; the former solution on cooling to 59°, retained 1·78, the solution of the opaque 2·9 of the acid; 100 water at common temperature dissolve 0·96 of the vitreous and 1·25 of the opaque. When slowly sublimed, arsenious acid crystallizes in regular octahedra of a brilliant lustre, but Wöhler observed in crystallized acid, arising from the calcination of cobalt-ores, thin, transparent, pearly, 6-sided laminæ,

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which were flexible and cleavable parallel to the predominating plane. When sublimed, the latter crystallize in regular octahedra, or they pass gradually and without heat into a milky mass composed of octahedra; but if the transparent kind be dissolved in muriatic acid, the separation of each octahedral crystal from the cooling solution is attended by a flash of light. When ammonia is poured over the vitreous acid, and afterwards washed out by water, the acid appears to have changed into the opaque variety. To obtain it in large crystals, pass sulphurous acid through a cold solution of arsenic acid. Wöhler. Arsenious acid has a faintly sweetish taste, leaving a rather acrid sensation, but its taste is not well defined. Strongly heated in a sealed vessel, it fuses to a transparent glass, but in open vessels it sublimates at 380°, first becoming soft but without previous fusion; the spec. grav. of its vapor is 13670. It is soluble in several acids, but does not appear to be electro-positive in reference to them; it is also soluble in oils and alcohol; some organic matters impair its solubility. It is decomposed with heat by carbon, hydrogen, sulphur, and phosphorus (the two last forming sulphuret and phosphuret), by potassium, sodium (the two last with combustion), and by other metals.

	H = 1	O = 100	In 100 pts.	Thénard.	Davy.	Proust.	Mitscherl.	Berzel.
As....	75·3	940·08	75·81	74·24	75	75·2	75·73	75·782
O ₃	24·0	300	24·19	25·76	25	24·8	24·27	24·218
	99·3	1240·08	100	100	100	100	100	100

Form., AsO₃ (As₂O₃, Berz.).

Uses. Arsenious acid or white arsenic is employed in glass-making to convert protoxide of iron into the sesquioxide, which colors the glass less; metallic arsenic is volatilized. See GLASS. It is also employed for making various arsenical preparations, which are used in the manufacture of Scheele's Green (see below) in calico-printing, &c. It is used to a limited extent in medicine. From its poisonous effects on the animal system, it has been administered to destroy life; from this property it may be usefully employed to protect organic specimens in natural history (stuffed animals) from the ravages of insects. See PRESERVATION.

3. *Arsenic Acid.* Syn. Acidum Arsenicum or Arsenicum. *Ger.* Arseniksäure. Prepared by boiling 8 pts. arsenious acid with 2 pts. concentrated chlorohydric acid of spec. grav. 1·2, and gradually adding 24 pts. nitric acid of spec. grav. 1·25, evaporating in glass to a syrup, then in platinum to a temperature near to ignition, at which point it is maintained until all the nitric acid is expelled.

Prop. Milk-white, anhydrous. It dries by evaporation to a syrupy mass, which becomes opaque when the water is expelled; if the dry acid be allowed to deliquesce slowly in the air, it forms at a certain point large crystals more deliquescent than chloride of calcium. Mits-

cherlich. By evaporating so far that at 248° it begins to deposit, a thick liquid is obtained of spec. grav. 2·55, containing 71 per cent. acid, which may be cooled to—15° without depositing. Vogel. It attracts moisture from the air until it has a spec. grav. = 1·935. Its solution reddens litmus strongly. Like dry phosphoric acid, it dissolves only partially in water, leaving a white powder, which dissolves slowly but entirely, especially by frequent agitation. A portion of the acid is decomposed by ignition, forming a fused, glassy mass, consisting of arsenic and arsenious acids, the former of which may be dissolved out by water; at a higher heat it is entirely volatilized as arsenious acid and oxygen. Heated with carbon, hydrogen, phosphorus, and most oxidable metals, it is reduced either to metal or arsenious acid. The dry acid absorbs sulphuretted hydrogen, forming water and sulphuret of arsenic; its solution is slowly decomposed by that gas, more rapidly by an alkaline sulphhydrate. It is precipitated white by an excess of baryta, strontia, and lime. In solution it is reduced to arsenious acid by sulphurous acid.

It is one of the strongest acids, neutralizing the alkalis perfectly, and by heat expelling all volatile acids from combination, even the sulphuric. It closely resembles phosphoric acid. See its salts below.

	H = 1	O = 100	In 100 pts.	Thomson.	Thénard.	Mitscherl.	Berzel.
As.....	75·3	940·08	65·28	65·62	65·4	65·04	65·283
O ₅	40·0	500·00	34·72	34·38	34·6	34·96	34·717
	115·3	1440·08	100	100	100	100	100

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Arseniuretted Hydrogen. *Ger.* Arsenikwasserstoffgas. It is formed when arsenic is in contact with nascent hydrogen. *Prep.* 1. By heating equal parts finely granulated zinc and powdered arsenic in an earthen retort, combustion and fusion ensue; pulverize finely and pour over it in a retort sulphuric acid, diluted with 3 times its weight of water. $\text{Zn}_3\text{As} + 3(\text{SO}_3, \text{HO}) = 3(\text{ZnO}, \text{SO}_3) + \text{AsH}_3$. *Soubeiran.* 2. Mix 2 pts. sulphuret of antimony, 2 cream of tartar, and 1 arsenious acid, and ignite to redness for 2 hours; place the regulus obtained (avoiding contact with the hands) under a bell-glass filled with freshly boiled water, when the gas is slowly evolved. *Serullas.* 3. Add muriatic acid to an aqueous solution of arsenious acid, and immerse a piece of zinc in it. $\text{AsO}_3 + \text{H}_6 = 3 \text{HO} + \text{AsH}_3$.

Prop. A colorless gas, of a disagreeable odor (which may not belong to the pure gas), highly poisonous; spec. grav. = 2.694; at -40° condenses into a clear, ethereal liquid, which rises again in vapor at a few degrees higher temperature; slightly soluble in water, not in a saline solution; kept over water containing air it slowly deposits arsenic; it has no action on litmus paper, and appears to have no affinity for alkalies or earths; depositing arsenious acid or metallic arsenic according to the supply of oxygen; burns with a brilliant white flame, detonates when mingled with oxygen or the air, either by flame or the electric spark; heated with sulphur, phosphorus, potassium, tin, &c., they unite with it eliminating hydrogen; if chlorine be passed up into arseniuretted hydrogen over mercury, each bubble inflames, forming chlorohydric acid and brownish fumes of metallic arsenic. A full red heat alone resolves it into the metal and hydrogen, the former being deposited a little beyond the flame in the glass tube through which the gas is streaming.

It is decomposed by nitric, nitromuriatic, boiling sulphuric acids, and by chlorine water, yielding water with metallic arsenic, arsenious or arsenic acid. It is not altered by chlorohydric or phosphoric acids, &c. The more reducible metallic oxides and their salts are decomposed by it, and the arsenic set free as metal or arsenious acid. In solutions of gold and silver, the noble metals are deposited and water and arsenious acid formed; in solutions of several other metals, such as copper, the hydrogen only is oxidized and an arseniuret precipitated. When passed over chloride of copper, heated to about 400° , both are decomposed, $3 \text{CuCl} + \text{AsH}_3 = \text{AsCu}_3 + 3 \text{HCl}$. It is absorbed by dry sulphate of copper, yielding water and a blackish compound of sulphuric acid and arseniuret of copper.

Its action on chloride of mercury (corrosive sublimate) is characteristic, so that it can be detected in other gases when only $\frac{1}{100,000}$ part is present; brought in contact with this salt, the latter is immediately coated with a mixture of arsenious acid and calomel, and the coating is then covered with a dark layer of metallic arsenic and mercury, which becomes darker. When the mutual action of the gas and the liquid has ceased, the other gases remain, and arsenious acid is in solution when the cor-

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subl. was in sufficient quantity; if this were not the case, the decomposition is imperfect, and by agitation an amalgam of mercury and arsenic is formed. The decomposition is instantaneous when the gas is passed through a concentrated solution. *Berz.*

Arseniuretted hydrogen is not changed by alcohol or ether; it dissolves sparingly in the fixed oils, giving them a darker color and greater consistence; oil of turpentine acts strongly on it, becoming thick, milky, reddening litmus, depositing small, white crystals, which, thrown on ignited coals, smell of arsenic and terpentine.

	H = 1	O = 100	In 100 pts.	By vol.
As....	75.3	940.08	98.05	1
H ₃	3	37.50	1.95	6
	78.3	977.58	100	4

Form., AsH_3 (As_2H_3 , *Berz.*) See testing for arsenic below.

Sulphurets of Arsenic. Arsenic and sulphur may be fused together in every proportion, the sulphur becoming darker and the streak more yellow. Subjected to distillation, sulphur passes over at first and becomes successively more arseniuretted. There are, however, several distinct sulphurets.

1. *Black Sulphuret of Arsenic.* Digest the red sulphuret (Realgar) with a solution of potassa. A brownish black powder, yielding by distillation common sulphuret of arsenic and then metallic arsenic. Form., As_6S , containing 3.44 per cent. sulphur.

2. *Bisulphuret of Arsenic.* Syn. Realgar, Red Sulphuret of A., Hyposulpharsenious acid. *Ger.* Unterarseniges Sulfid, Roth's Arsenikglas, Arsenikrubin. For its manufacture, see the Treatment of Arsenical Ores above. For the native compound see REALGAR. The artificial compound is opaque, brownish, or blood-red, or even transparent, ruby red; of conchoidal fracture; fuses and distills over unchanged, burns with bluish flame, and an odor of sulphurous acid and metallic arsenic; is insoluble in water and alcohol. Nitric acid oxidizes the arsenic, then the sulphur; it deflagrates with saltpeter. It combines with sulpho-bases, forming salts of difficult solubility in water.

	H = 1	O = 100	In 100 pts.
As....	75.3	940.08	70.03
S ₂	32.2	402.33	29.97
	107.5	1342.41	100

Form., AsS_2 (As_2S_2 , *Berz.*).

3. *Sulpharsenious Acid.* Syn. Orpiment, Yellow Sulphuret of A., Tersulphuret of A. *Ger.* Opermert, Rauschgelb, Gelbes Arsenikglas, Auripigment; Arseniges Sulfid, *Berz.* For the mineral see ORPIMENT. *Prep.* 1. See Treatment of Arsenical Ores above. 2. Precipitate a muriatic solution of arsenious acid or an arsenite by sulphuretted hydrogen.

Prop. It has a bright yellow color, passing into orange; is opaque; the fused has a flat conchoidal fracture, is crystalline after cooling; it is slightly soluble in water, as when an aqueous

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and not acid solution of arsenious acid is precipitated by sulphuretted hydrogen. It is insoluble in acids, is oxidized by nitric and nitro-muriatic acid; soluble with a yellow color in caustic and carbonated alkalies, expelling carbonic acid, and forming solutions of alkaline arsenite and sulpharsenite; it absorbs ammonia and is converted into a yellow powder. Heated in close vessels, it fuses and sublimes; in open vessels it burns with a pale bluish flame. It is one of the strongest sulphoacids. See its salts below.

	H = 1	O = 100	In 100 pts.	Berz.
As....	75.3	940.08	60.90	61
S ₃	48.3	603.50	39.10	39
	83.6	1543.58	100	100

Form., AsS_3 (As_2S_3 , Berz.).

Use. Both realgar and orpiment have been and are still somewhat employed as pigments in oil-painting and lacquering; but the King's Yellow is a mixture of arsenious acid and orpiment, and should never be employed, from its poisonous character. They are also used for reducing indigo, which dissolves in the potassa employed at the same time. Orpiment has been applied to silks, &c., by dissolving it in ammonia, passing the goods through the solution, and hanging them in a stove-room to remove the ammonia and fasten the color. Realgar was formerly employed for a white fire in fire-works, but is now rarely used; the composition is 24 saltpeter, 7 sulphur, and 2 realgar. For all the objects named, both sulphurets should be abandoned for the greater or less injurious effects resulting from their use.

4. *Sulpharsenic Acid.* Syn. Persulphuret of A., Arseniksulfid, Berz. Prepared by passing sulphuretted hydrogen through a moderately strong solution of arsenic acid, or an alkaline arseniate, and adding muriatic acid in the latter case. It closely resembles 3 in color, but has a lighter yellow tint. It fuses at a higher temperature than sulphur, and becomes reddish and darker; distils over as a tough, reddish brown amorphous mass, which is transparent and yellowish red when cold. Boiled with alcohol before fusion, sulphur is extracted, and the sulphuret has a deeper color. It reddens litmus temporarily when held in steam or boiled in the blue fusion. It readily dissolves in the caustic alkalies, alkaline earths and strong ammonia, expels sulphuretted hydrogen from the sulphhydrates, and carbonic acid from neutral and bicarbonates. See its salts below.

	H = 1	O = 100	In 100 pts.
As....	75.3	940.08	48.31
S ₅	80.5	1005.83	51.69
	155.8	1945.91	100

Form., AsS_5 (As_2S_5 , Berz.).

5. *Hypersulphuret of Arsenic.* Arsenikübersulfid, Berz. Precipitate a neutral solution of sulpharseniate of potassium or sodium by alco-

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hol, distil off $\frac{2}{3}$ of the alcohol from the filtered liquid; it deposits small, yellow, shining, crystalline scales as fusible as sulphur, and containing traces of the alkaline sulphuret. A slow evaporation of the remaining liquid often deposits a lower sulphuret of a red color. The hypersulphuret contains 26.61 As + 79.39 S = 100. Form., AsS_{18} (AsS_9 , Berz.).

Seleniuret of Arsenic. Add arsenic to fused selenium. It is black, very fusible, less volatile than either of its elements, so that an excess of either can be volatilized. At a red heat it boils, giving a sublimate which appears to be a perseleniuret; the residue then flows quietly, but at a full white heat it also distils over in drops, which, on cooling, are black, with brownish tint, with a brilliant surface and vitreous fracture.

Phosphuret of Arsenic is formed by fusing equal parts of phosphorus and arsenic in a retort or under water. It is black, shining, brittle, and must be kept under water.

Alloys of Arsenic. 1. *Potassium and Sodium.* Arsenic combines readily with these metals with the evolution of much heat; the alloy placed in water decomposes it, evolving arseniuretted hydrogen, while the alkaline metal is oxidized and arsenic separates in brown flocculæ. Boiled with a concentrated solution of caustic potassa, arsenic is acidified and hydrogen evolved; heated with fused aqueous caustic potassa, some arsenite of potassa is formed and hydrogen evolved; but the brown color of the mass is due to arseniuret of potassium, and evolves arseniuretted hydrogen in water. If the heat be carried fully to redness, the arsenite is changed to arseniate; arsenic is partly sublimed and partly acts on more of the potassa, forming arseniate and arseniuret of potassium. The action is similar but less energetic with caustic soda, and almost ceases with the alkaline earths, even when the vapor of arsenic is conducted over them.

2. *Aluminium.* When heated together to ignition, they unite with combustion. A dark-gray powder evolving arseniuretted hydrogen slowly in cold, rapidly in hot water.

3. *Glucinum.* Formed similarly and has similar properties.

II. SALTS.

Arsenic forms a few compounds with the halogen bodies, which are included under the salts like the similar compounds of other metals. Of the oxysalts there are two classes, arsenites and arseniates. Of sulphosalts there are three classes, hyposulpharsenites, sulpharsenites, and sulpharseniates.

HALOGEN COMPOUNDS.

Bichloride of Arsenic. Prep. Introduce into a tubulated retort a mixture of 1 pt. arsenious acid and 10 pts. by weight of oil of vitriol, heat it to 212°, and add, in successive portions, fragments of sea-salt, and collect the chloride in cooled vessels. A little water passes over towards the close of the operation, but the hydrated portion swims on the surface of the rest. The pure chloride may be separated from the hydrated by distilling the mixture with oil of

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vitriol. Form., AsCl_2 . *Gmelin and Dumas.* By distilling a mixture of metallic arsenic and calomel, a dark brown sublimate is obtained, and arsenical amalgam remains in the retort. It is probably a bichloride of arsenic + subchloride of mercury. It is insoluble in water; caustic potassa dissolves out arsenious acid, forming chloride of potassium and arsenical amalgam. *Berz.*

Terchloride of Arsenic. Syn. Sesquichloride of A., Fuming liquor of A., Arseniksüberchlorür, *Berz.* *Prep.* When powdered arsenic is thrown into chlorine at common temperatures, it inflames spontaneously, producing white fumes of the terchloride. It is best obtained by distilling a mixture of 1 pt. metallic arsenic + 6 pts. corrosive sublimate.

Prop. A colorless, oily, heavy liquid, fuming in the air, boiling at 270° , and not congealing at -20° . Decomposed by water into arsenious and chlorohydric acids. It dissolves sulphur and phosphorus by warm digestion, but they separate on cooling; it absorbs 10 times its volume of chlorocarbonic acid, which is evolved upon the addition of water; it unites with oil of terpentine, resin, and olive oil. Form., AsCl_3 , which, therefore, corresponds with arsenious acid. *Berz.* It absorbs ammoniacal gas, forming a white powder, soluble in water; it consists of 75.14 per cent. terchloride of arsenic and 24.86 per cent. ammonia; its formula is therefore $2\text{AsCl}_3 + 7\text{NH}_3$, and by solution in water, produces salammoniac and binarsenite of ammonia. $2\text{AsCl}_3 + 7\text{NH}_3 + 7\text{HO} = 6\text{NH}_4\text{Cl} + \text{NH}_4\text{O} + 2\text{AsO}_3$. *Rose.*

Terbromide of Arsenic. Add gradually to bromine powdered arsenic, and when combustion ceases, distil. A colorless or slightly yellowish liquid, crystallizing in the receiver, by cooling the gas it forms long prisms; congeals at 68° ; becomes liquid between 68° and 77° , boils at 428° ; it fumes but slightly in the air, but is deliquescent; with much water, decomposes like the terchloride. Form., AsBr_3 .

Teriodide of Arsenic. Digest 3 pts. finely powdered arsenic, 10 pts. iodine, and 100 pts. water as long as the odor of iodine is perceived, evaporate the clear liquid, which, at a certain state of concentration, yields red crystals of the teriodide; to obtain it anhydrous, evaporate to dryness, and heat it to fusion, it is then brick-red and crystalline. *Plisson.* In a flask with a long and wide neck fuse 1 pt. arsenic and 3 pts. iodine, heat to sublimation and remove the shining red crystals from time to time; or dissolve the mass in boiling alcohol to saturation, when darker colored crystalline scales separate from the solution. *Bette.* It is soluble in a large quantity of water, but with less water, iodohydric acid dissolves, and white crystalline scales separate, which consist of variable quantities of arsenious acid, teriodide of arsenic, and water; this compound loses water and becomes yellow by a gentle heat, but at a higher temperature, iodide of arsenic sublimes, followed by arsenious acid. *Plisson.* Form. of the teriodide, AsF_3 . It is apt to contain arsenious acid, especially when prepared in the moist way.

Terfluoride of Arsenic. Prepared by distilling

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a mixture of fluor spar, arsenious and sulphuric acids. A colorless, fuming liquid, spec. grav. = 2.73, decomposed by water into fluorhydric and arsenious acids, by glass into fluosilicic and arsenious acids.

OXYSALTS.

Arsenites.

Ger. Arsenigsäure Salze. The alkaline salts may be prepared by the direct action of arsenious acid and potassa, soda or ammonia; they are very soluble in water, and have an alkaline reaction; most other formed by double decomposition are insoluble or sparingly soluble in water; but all are dissolved by acids which do not form insoluble compounds with their bases. The soluble arsenites are characterized by forming a yellow precipitate with a strong neutral solution of nitrate of silver, a peculiar green (Scheele's) with salts of copper; when acidulated, they precipitate orpiment immediately with sulphuretted hydrogen. The insoluble are readily decomposed by caustic alkali or by boiling with carbonates of potassa or soda. They are all decomposed by heat in close vessels, arsenious acid being sublimed, or an arseniate formed, and metallic arsenic sublimed. With black flux or formiate of soda, they are easily reduced. Before the blowpipe they reduce easily, giving the characteristic arsenical odor.

Arsenite of Potassa, $2\text{KO}, \text{AsO}_3$, white, amorphous mass, it is the active ingredient in Fowler's solution; it is best obtained by decomposing arsenite of baryta by sulphate of potassa; A. of soda, white granular, crystalline; of ammonia, known only in solution; of baryta, white powder; of strontia, soluble. Neutral arsenite of lime, $2(2\text{CaO}, \text{AsO}_3) + 3\text{HO}$, is obtained by precipitating lime-water with arsenious acid, leaving an excess of lime in solution; it attracts carbonic acid from the air, forming carbonate of lime and the following acid salt. The latter is obtained by saturating alkali with as much arsenious acid as it can take up, and precipitating with a salt of lime; it is much looser powder and permanent in the air; formula, $2(\text{CaO}, \text{AsO}_3) + \text{HO}$. Both are converted by a strong heat into arseniate of lime, with the development of metallic arsenic. A. of magnesia is white, insoluble. *Protarsen.* of iron, $2\text{FeO}, \text{AsO}_3 + 7\text{aq.}$, white, soluble in caustic ammonia. The neutral *perarsenite* of iron consists of $2\text{Fe}_2\text{O}_3, 3\text{AsO}_3 + 7\text{HO}$. Guibout found that when fresh and moist, hydrated peroxide of iron is digested to saturation, with a solution of arsenious acid, it forms the compound, $4\text{Fe}_2\text{O}_3, \text{AsO}_3 + 12\text{HO}$. The *arsenite of cobalt*, $2\text{CoO}, \text{AsO}_3$, insoluble, rose-red, changed by nitric acid into arseniate, decomposed by caustic potassa, dissolved by caustic ammonia; of nickel, $2\text{NiO}, \text{AsO}_3$, insoluble, apple-green, becoming first black by ignition, subliming arsenious acid and leaving a light green basic salt. (See COBALT and NICKEL-BLOOM.) The salt of lead, PbO, AsO_3 , formed by arsenite of ammonia and sugar of lead, and a basic, $2\text{PbO}, \text{AsO}_3$, by basic acetate of lead, are both white powders, containing combined water, and fuse by heat to a yellowish glass, which become

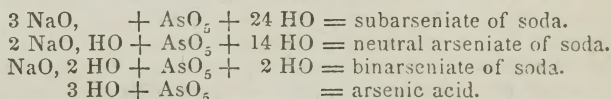
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strongly electric. Arsenite of *peroxide of tin*, 2SnO , AsO_3 , is a gelatinous insoluble powder, unchanged by ignition, and requiring a high heat for fusion.

Arsenite of Copper, 2CuO , AsO_3 , produced by digesting carbonate of copper with water and arsenious acid, is a green solution, precipitable neither by acids nor alkalis, giving, by evaporation, a yellowish green salt, which appears to have an excess of acid. The green neutral salt is obtained by adding arsenite of potassa to sulphate of copper; with an excess of alkali, the color is richer, but soon changes to dark brown, containing arseniate of oxide and arsenite of suboxide.

Scheele's Green. Scheele gave the following method of preparing this color. Dissolve 2 lbs. sulphate of copper in 3 galls. warm water; in another vessel dissolve 2 lbs. pure potash and 11 ozs. arsenious acid in 1 gall. water, filter both through linen, and add the latter portionwise, with constant stirring, to the former while still warm; let the precipitate settle, draw off the clear liquid, pour over it a gallon or more hot water, and wash it with a second portion; throw it on a filter and dry by a gentle heat. The above proportions give 1 lb. $6\frac{1}{2}$ ozs. of the green. It is employed as a pigment.

Arsenite, with Acetate of Copper, first made in 1814 at Schweinfurth, and hence called *Schweinfurth Green*; is an exceedingly brilliant green pigment. Upon mixing strong solutions of arsenious acid and acetate of copper, the precipitate is arsenite of copper (*Ehrmann*) of an olive green color, and acetic acid is set free; but if they remain together for a long time, or be boiled for a few minutes, the precipitate becomes a brilliant green. Diffuse 10 pts. verdigrise through sufficient warm water to make a thin paste and pass it through a sieve. Dissolve 8—9 pts. finely powdered arsenious acid in 100 pts. water, filter hot and, while still boiling, add to it gradually the infusion of verdigrise; a few minutes boiling is sufficient to produce the full tone of color. If cold water be added, after the hot solutions are mixed, without boiling, the change is retarded, but the color is richer and more crystalline. *Ehrmann's* analysis gave



The binarseniates are soluble, the others insoluble, or sparingly soluble, in water, excepting the alkaline salts. The insoluble dissolved in nitric acid, or muriatic acid, produce, with basic acetate of lead, basic arseniate of lead, which fuses by the blowpipe, giving off abundant arsenical fumes. Any of the arseniates may be reduced by the blowpipe, and yield the characteristic arsenical fumes. They are distinguished from the arseniates by giving a reddish brown precipitate with a salt of silver; their dilute and acidulated solutions are decomposed with much greater difficulty by sulphuretted hydrogen, which produces the light, yellow sulphuret, AsS_3 .

Arseniate of Potassa. *Ger.* Arseniksaures Kali.

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Oxide of copper	31-243
Arsenious acid	58-622
Acetic acid.....	10-135

100

According to which its formula is $\text{CuO}, \bar{\text{A}} + 3(2\text{CuO}, \text{AsO}_3)$.

Both the above greens are employed as pigments, but in using them it should not be forgotten that they are highly poisonous.

Arsenite of Black Oxide of Mercury, prepared by double decomposition, or by digesting mercury with arsenic acid; is a white powder insoluble in water, soluble in chlorohydric acid. The salts of the red oxide is white, insoluble, soluble in arseniate of potassa with a brown color.

Arsenite of Silver, prepared by double decomposition, is a yellow powder, gradually changing to a dark gray color. See Testing for Arsenic, below.

Arsenite of Antimony, formed by digesting antimony with a strong solution of arsenic acid and precipitating by water.

Sulphate of Arsenious Acid. Schafhäutl observed a deposit in the flues from the calcination of copper-ore in South Wales, forming small crystalline laminæ, so extremely deliquescent as to evolve heat by attracting moisture from the air; water decomposed them. They consisted of

Arsenious acid	68 250
Sulphuric acid	27-643
Protoxide of iron.....	3-029
Oxide of copper.....	0-420
Oxide of nickel	0-656

99-998

Their formula, omitting the metallic salts, is $\text{AsO}_3 + \text{SO}_3$.

Arseniates.

Ger. Arseniksaure Salze. The arseniates closely resemble the corresponding salts of phosphoric acid, but as far as known, are only tribasic. One or more of the 3 equivalents of basic water may be replaced by an equiv. of a metallic oxide, and are called acid, neutral, and subsalts. Thus we have

The *neutral* salt is obtained by saturating arsenic acid with potassa, or by fusing arsenious acid and caustic potassa; in the latter case, the arsenious acid is oxidized by the oxygen of the water and hydrogen liberated. It is a deliquescent saline mass. Form., 2KO , $\text{HO} + \text{AsO}_5$.

The acid or *binarseniate* is formed by adding as much more arsenic acid to the neutral salt, or by adding until litmus-paper dipped into it retains its redness; formed also by igniting equal parts of arsenious acid and saltpeter; dissolve in water, evaporate to crystallization. The crystals belong to the quadratic system and are unalterable in the air. Form., KO , $2\text{HO} + \text{AsO}_5$.

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The basic or *subarsenate* is formed by adding potassa to the neutral salt and concentrating by evaporation. Fine, deliquescent needles. Form., $3\text{KO} + \text{AsO}_5$.

Arsenate of Soda. 1. *Neutral.* Add carbonate of soda to a hot solution of arsenic acid as long as effervescence occurs; the solution has an alkaline reaction. It forms large efflorescent crystals, containing 24 eq. crystal-water. Form., $2\text{NaO}, \text{HO} + \text{AsO}_5 + 24\text{aq.}$ When a concentrated solution evaporates spontaneously at about 68° , it forms different crystals, of the formula, $2\text{NaO}, \text{HO} + \text{AsO}_5 + 14\text{aq.}$

The *acid* salt is obtained by adding to the preceding as much more arsenic acid, or by adding the acid until the solution ceases to precipitate chloride of barium. It forms large, permanent crystals of the right-rhombic system, containing 19.72 per cent. water. Form., $\text{NaO}, 2\text{HO} + \text{AsO}_5 + 2\text{aq.}$

The *basic* salt is formed by adding caustic soda to the neutral salt, evaporating rapidly, and setting aside to crystallize. It forms 6-sided prisms, containing 50.82 per cent. water; 100 pts. water dissolve 28 pts. at 60° ; they are unalterable in the air, and fuse at 186° ; the solution absorbs carbonic acid from the air. Form., $3\text{NaO}, \text{AsO}_5 + 24\text{aq.}$

Arsenate of Potassa and Soda. Add carbonate of soda to binarsenate of potassa as long as effervescence occurs. Form., $2\text{KO}, \text{AsO}_5 + 2\text{NaO}, \text{AsO}_5 + 17\text{aq.}$

Arsenate of Ammonia. 1. *Neutral.* Add ammonia to a strong solution of arsenic acid, until a precipitate begins to form, and suffer it to evaporate spontaneously. It forms large oblique rhombic prisms containing 15.33 per cent.

Basic.....	$3\text{CaO} + \text{AsO}_5$.
Picropharmacolite.....	$5\text{CaO} + 2\text{AsO}_5 + 12\text{HO.}$
Haidingerite.....	$\text{HO}, 2\text{CaO} + \text{AsO}_5 + 3\text{HO.}$
Pharmacolite.....	$\text{HO}, 2\text{CaO} + \text{AsO}_5 + 5\text{HO.}$
Acid.....	$2\text{HO}, \text{CaO} + \text{AsO}_5$.

Arsenate of Lime and Ammonia. Add a warm solution of basic arseniate of ammonia to a warm solution of nitrate of lime. It crystallizes out in small rhombic plates, is difficultly soluble in water. Form., $2\text{CaO}, \text{AsO}_5 + \text{NH}_3 + 14\text{HO.}$

Arsenate of Magnesia. The *neutral*, $2\text{MgO}, \text{HO}, \text{AsO}_5$, is insoluble; the *acid*, $\text{MgO}, 2\text{HO}, \text{AsO}_5$, is soluble and dries to a gummy mass.

Arsenate of M. and Ammonia resembles the salt of phosphoric acid, and is obtained in a similar manner.

Arsenate of Alumina. The *neutral*, $2\text{Al}_2\text{O}_3 + 3\text{AsO}_5$, is insoluble in water, but soluble in arsenic acid, forming the acid salt. A. of *Glucina* resembles it. The salt of *Yttria* is insoluble, and changed to a basic salt by ammonia. A. of *Zirconia* is insoluble. A. of *Thorina* is insoluble in water and an excess of arsenic acid. A. of protoxide of *Cerium* is insoluble in water, soluble in arsenic acid, forming an uncrystallizable basic salt.

A. of *Manganese* is white, insoluble in water, soluble in excess of acid. A double salt is formed by adding a warm solution of chloride of manganese to a warm solution of basic arseniate of ammonia; it is a crystalline

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water, which effloresce in the air, losing ammonia and becoming 2. Form., $2\text{NH}_3\text{O}, \text{HO} + \text{AsO}_5$, or $2\text{NH}_3 + \text{AsO}_5 + 3\text{HO.}$

2. *Acid.* The binarsenate is formed by the efflorescence of 1, or by supersaturating 1 with arsenic acid. It contains 16.93 per cent. water. Form., $\text{NH}_4\text{O}, 2\text{HO} + \text{AsO}_5$, or $\text{NH}_3 + \text{AsO}_5 + 3\text{HO.}$ The *basic* arseniate is difficultly soluble.

Arsenate of Baryta. 1. *Neutral.* Add a solution of arseniate of soda ($2\text{NaO}, \text{AsO}_5$) to a solution of chloride of barium. The first precipitate redissolves, and the neutral salt then separates as a white, scaly, crystalline mass; difficultly soluble in water, which separates it into basic and acid salts; it contains 11.82 per cent. water. Form., $2\text{BaO}, \text{HO} + \text{AsO}_5 + 3\text{aq.}$

2. *Basic.* Wash the preceding well with boiling water, or the precipitate made with $3\text{NaO}, \text{AsO}_5$. A white, insoluble powder. Form., $3\text{BaO} + \text{AsO}_5$.

3. *Acid.* Formed by dissolving either of the preceding in arsenic acid, or by adding baryta to arsenic acid until a precipitate begins to form. It is very soluble, and may be crystallized. Form., $\text{BaO}, 2\text{HO} + \text{AsO}_5$. If chloride of barium be added to an excess of arseniate of soda, the acid salt is in solution and the precipitate is a mixture of neutral and basic. The carbonic acid of the air affects these arseniates. An insoluble hyperbasic salt is formed by treating the above with ammonia. Form., $5\text{BaO} + 2\text{AsO}_5$.

Arsenate of Strontia resembles that of baryta.

Arsenate of Lime. Formed similarly to the salt of baryta, acid, neutral and basic. The neutral and hyperbasic salts occur as minerals. They all have the following formulæ:

powder, white, with a reddish tint. Form., $2\text{MnO}, \text{AsO}_5 + \text{NH}_3 + 12\text{HO.}$

Protarsenate of Iron precipitates as a white powder, changing to a dirty green by partial oxidation, is slightly soluble in ammonia. Form., $2\text{FeO}, \text{AsO}_5$. By distillation it becomes gray, subliming arsenious acid and leaving the iron higher oxidized. *Perarsenate* is a white powder, insoluble in water, soluble in acids; when heated gently it loses water and becomes red, but heated nearly to ignition, it exhibits a feeble combustion, becoming yellowish. Form., $2\text{Fe}_2\text{O}_3, 3\text{AsO}_5 + 12\text{HO.}$ The fresh precipitate dissolves in ammonia to a clear red solution, which loses ammonia by standing, and dries down to a ruby-red mass, which is a basic double salt. A *basic* perarsenate is obtained by oxidizing the neutral protarsenate by nitric acid, evaporating or precipitating by ammonia. Form., $\text{Fe}_2\text{O}_3 + \text{AsO}_5$. Caustic potassa removes a portion of acid, forming a still more basic salt, which, at a commencing red heat, exhibits a lively combustion. For the mineral arseniates of iron, see *CUNE-ORE*, *IRON-SINTER*, *SCORODITE*.

Arsenate of Cobalt forms a rose-red powder, insoluble in water, soluble in excess of acid, in

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muriatic acid with a red, in ammonia with a purple color. The basic salt occurs native; see COBALT-BLOOM. An arseniate is prepared on a large scale, called *Chaux Metallique*, either, 1, by dissolving a good arsenical cobalt ore in nitric acid, precipitating by potash until the white precipitate (arseniate of iron) begins to be red, and then precipitating the clear liquor drawn off by potash; or, 2, the ore is simply calcined to expel sulphur and part of the arsenic; or, 3, ignited with potash and a little quartz, which remove sulphur, copper, iron, and arsenic, and leave a richer *speise* or arseniuret of cobalt; this is powdered and again fused with potash, leaving a *speise*, free from iron, which is carefully calcined at first gently, then more powerfully with free access of air. This basic arseniate of cobalt is employed to communicate a blue color to twice as much alumina, to color glass, to paint on enamel and porcelain. See COBALT.

A. of Nickel. A pale, green, insoluble powder, soluble in excess of acid; ignited it loses crystal-water, assuming first a hyacinth red, then a light-yellow color. Form., $2\text{NiO}, \text{AsO}_5$. According to Berthier, it is basic salt. For the native salt, see NICKEL-BLOOM.

A. of Zinc. The neutral salt, $2\text{ZnO}, \text{AsO}_5$, is a white insoluble powder, dissolving in arsenic acid, and crystallizing from the solution as an acid salt in cubical crystals. It is also formed by digesting zinc with liquid arsenic acid, arseniuretted hydrogen being evolved.

A. of Lead is a white, insoluble powder, soluble in nitric and chlorohydric acids, fusing at a white heat to an opaque, yellowish glass. Form., $2\text{PbO}, \text{AsO}_5$. The basic salt, $3\text{PbO}, \text{AsO}_5$, prepared by treating the neutral salt with ammonia, is a white, insoluble powder. When a neutral arseniate is mixed with neutral acetate of lead, the basic salt precipitates, and free acetic acid is in the solution. For the native compounds, see ARSENIO-PHOSPHATES.

A. of Bismuth is insoluble in water and nitric acid, soluble in chlorohydric. The salt of *Uranium* is light yellow, insoluble. The neutral salt of *Copper*, $2\text{CuO}, \text{AsO}_5$, precipitates as an insoluble, green powder. Several basic salts are found as minerals. See APHANESITE, COPPER-FROTH, COPPER-MICA, ERINITE, EUCHROITE, LIROCONITE, OLIVENITE, and the general article CUPREOUS ARSENIO-PHOSPHATES.

A. of black oxide of Mercury, $2\text{Hg}_2\text{O}, \text{AsC}_5$, is a white insoluble powder, soluble in chlorohydric acid. The salt of the red oxide is yellow, insoluble in an excess of acid. **A. of Silver.** Only the basic salt is known, $3\text{AgO}, \text{AsO}_5$; it is a reddish brown powder, soluble in acids. The salt of *Palladium* is a yellow powder.

A. of Antimony is a white powder. The protosalt of *Molybdenum*, $2\text{MoO}, \text{AsO}_5$, formed by chloride of molybd., MoCl_3 , and arseniate of soda, is dark gray, closely resembles the phosphate. The persalt is formed from the bichloride, MoCl_5 . An acid salt is obtained by dissolving the hydrated oxide of molybd. in arsenic acid; it has a strong tendency to become blue. Arseniate of molybdic acid forms a colorless solution and a lemon-yellow basic salt; the solution evaporated to a syrup crystallizes; alcohol decomposes the crystals, separating

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white flocculæ, which it redissolves. **A. of oxide of Vanadium**, $\text{VO}_2, \text{AsO}_5$. A solution of it, with excess of acid, deposits a granular crystalline crust of a light blue color; the excess of acid can be removed by washing; almost insoluble in water, or water containing arsenic acid, very soluble in chlorohydric acid; alcohol precipitates it. By treating this salt with nitric acid, it gives a lemon-yellow arseniate of vanadic acid, which resembles the phosphate. Arseniate of Chromic oxide is a green precipitate.

SULPHOSALTS.

Hyposulpharsenites. They are formed in the dry way by fusing realgar with sulphobases, or sulpharsenites with arseniurets. They are decomposed by water, changing into sulpharseniates, and depositing brownish black sulphuretted of arsenic. They are obtained in the humid way by boiling orpiment with a somewhat concentrated solution of carbonate of potassa or soda and filtering, when the salt separates on cooling as brown flocculæ. They are also formed by evaporating sulpharsenites. They are red or dark brown, generally insoluble in water; the alkaline are decomposed by pure water into a soluble basic and an insoluble acid salt; acids separate realgar.

Hyposulpharsenite of Potassium. Its solution in water is dark red, containing the basic salt; the precipitate is the bi-salt, $\text{KS}, 2\text{AsS}_2$. It fuses to a dark-red, transparent mass; soluble in water. The salt of sodium resembles that of potassium. The salt of ammonium deposits as a dark-brown crust from a very concentrated solution of sulpharsenite kept for a long time in a bottle. The salt of barium is a red, insoluble powder; of calcium and magnesium reddish brown; of zirconium dark brown; of manganese, a dark red precipitate.

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They are prepared neutral and solid in the dry way, for their solutions, by concentration, deposit a brownish hyposulpharsenite, while the liquid contains sulpharseniate. The alkaline salts are not decomposed by distillation, the rest are decomposed, orpiment passing over, while the residue is either a basic salt or the sulphobase alone. They resemble the sulpharseniates in their reaction with oxides, acids, &c., and under the influence of the air. Form., $(1, 2, \text{ or } 3) \text{MO} + \text{AsS}_3$.

Sulpharsenite of Potassium. Dissolve orpiment in sulphhydrate of potassium at common temperatures, until sulphuretted hydrogen ceases to evolve. The solution contains the bisulpharsenite, KS, AsS_3 , but it deposits the following salt as a brown powder. The neutral salt is obtained by heating neutral sulpharseniate in a retort, when sulphur sublimes and the sulpharseniate remains as a fused mass; yellowish when cold. By heating carbonate of potassa in a retort, with orpiment in excess, and distilling off the excess, an acid sulpharsenite is obtained. The sulpharsenites of sodium and lithium resemble the salt of potassium. The neutral salt of ammonia, $2\text{NH}_4\text{O}, \text{AsS}_3$, is formed by dissolving orpiment in caustic and sulphhydrated ammonia. If alcohol be added to the solution, containing an excess

of sulphhydrate, it deposits white, feathery crystals, which are the basic salt. Bineau found that orpiment absorbed so much dry ammonia as to produce the formula, $\text{NH}_3, 2 \text{AsS}_3$.

The neutral salt of *barium*, $2 \text{BaS}, \text{AsS}_3$, is reddish brown, very soluble in water, from which solution alcohol precipitates the basic salt in crystalline flocculæ. The neutral salt of *calcium* is obtained by digesting orpiment with slacked lime and water; the colorless solution yields, by evaporation, fine feathery crystals of a basic salt, and the amorphous brown neutral salt. If alcohol be added to a solution containing an excess of sulphuret of calcium, the solution contains the neutral salt, and the white precipitate has the composition, $3 \text{CaS}, \text{AsS}_3 + 15 \text{aq}$. The neutral salt of *magnesium* is light brown, amorphous, soluble in water and alcohol; a concentrated solution, cooled to 23° , separates into sulpharseniate and hyposulpharsenite. The salt of *glucinum* is a light yellow precipitate, somewhat soluble. The salts of *yttrium* and *zirconium* resemble it closely.

Sulpharsenite of Protosulphuret of Cerium. $2 \text{CeS}, \text{AsS}_3$, is a brilliant orange-yellow precipitate, somewhat soluble, more brilliant when dry; it fuses at commencing redness, becoming transparent, loses some of its sulpharsenious acid, but retains its fluidity and transparency; it is easily calcined into sulphate. The salt of *manganese*, $2 \text{MnS}, \text{AsS}_3$, is an orange-yellow precipitate, darkening by drying, with a dark-yellow streak. It yields orpiment by sublimation, leaving a yellowish green, infusible powder, a basic anhydrous salt. The salt of *protosulphuret of iron* is brownish black, slightly soluble in an excess of the precipitant, with a brownish yellow color; it decomposes, by drying, into oxide of iron and the following compound. The salt of *sesquisulphuret of iron* is an olive-green precipitate, somewhat soluble in excess of the precipitant, with a black color; when dry it is green, readily fusible, becoming yellowish and translucent, with a yellowish green powder before and after fusion. Both salts yield up their sulphuret of arsenic by distillation, leaving sulphuret of iron free from arsenic. The salt of *cobalt* is dark brown, soluble in an excess of the precipitant, becoming black on drying; that of *nickel* black, remaining so when dry. The salt of *zinc* is lemon-yellow, voluminous, pale orange-yellow when dry; sublimation at a red heat leaves a yellow basic salt, at a white heat sulphuret of zinc. The *cadmium* salt is pale yellow, drying to orange-yellow, fusible, and leaving, by distillation, a basic compound.

Sulpharsenite of Lead, $2 \text{PbS}, \text{AsS}_3$, is reddish brown, black when dry, fusing readily without decomposition; of *protosulphuret of tin*, $2 \text{SnS}, \text{AsS}_3$, dark reddish brown, when dry and moist, yielding a portion of its orpiment by sublimation; of *bisulphuret of tin*, $\text{SnS}_2, \text{AsS}_3$, yellow, orange-yellow when dry, distilling like the preceding; of *bismuth*, reddish brown, nearly black when dry, fusible, leaving a basic salt by sublimation of orpiment; of *uranium*, dark yellow, fusible, yielding part of its orpiment; of *sulphuret of copper*, $2 \text{CuS}, \text{AsS}_3$, is dark brown, drying to blackish brown. The salt of *disul-*

phuret of Mercury, $2 \text{Hg}_2\text{S}, \text{AsS}_3$, is black, decrepitating by heat with explosive force, yielding metallic mercury, and the salt of *sulphuret of mercury*, $2 \text{HgS}, \text{AsS}_3$; the latter is an orange-red voluminous precipitate, which, when the liquid contains an excess of corrosive sublimate, soon becomes white; by drying, the red color becomes brownish; it fuses and yields a sublimate, which is *bisulpharsenite*. The sulpharsenite of *silver*, $2 \text{AgS}, \text{AsS}_3$, is light brown, becoming black; a saturated solution of chloride of silver, in ammonia, added to a bisulpharsenite, produces a yellow precipitate of a 5-fold basic sulpharsenite of silver. The salt of bisulphuret of *platinum*, $\text{PtS}_2, \text{AsS}_3$, is dark yellow, becoming dark brown or black; it fuses, parting with orpiment, but a white heat does not remove all of the arsenic or sulphur. The salt of *gold*, $2 \text{Au}_2\text{S}_3, 3 \text{AsS}_3$, is yellow, becoming black; fuses easily, giving off some orpiment, and after cooling is dark, yellowish red, and transparent; a white heat leaves metallic gold. Sulpharsenite of *chrome* is grayish yellow, becoming greenish yellow by drying; it fuses, yielding orpiment, and even at a high heat it retains a portion; it easily calcines in the air to oxide of chrome.

SULPHARSENATES.

These salts vary in color, being generally yellowish or brownish, they have a peculiar hepatic taste, are decomposed by acid with the evolution of sulphuretted hydrogen, which can always be perceived except when too dilute; the alkaline and earthy and a few metallic salts are generally soluble, the rest insoluble. They form neutral and basic and acid salts, the basic being usually crystallizable, and the acid salts rare; the neutral are converted into sulpharsenites by dry distillation; the alkaline basic are not decomposed by a white heat, the other basic salts are more or less decomposed; they are all readily calcined in the air, becoming oxide, sulphate, or arseniate. Their strong solutions keep in the air, the dilute decompose slowly; they are so decomposed by oxymetallic solutions that oxarseniate is formed and basic sulpharseniate precipitates. They have a tendency to form double salts, and the alkaline salts dissolve the metallic sulpharsenates. Their general formula is $(1, 2, 3) \text{MS} + \text{AsS}_3$.

Sulpharseniate of Potassa. 1. *Neutral*. Pass sulphuretted hydrogen through neutral oxarseniate, or digest the sulphuret of arsenic, AsS_3 , with sulphhydrate of potassium. A tough, yellow mass, exhibiting some signs of crystallization. Form., $2 \text{KS}, \text{AsS}_3$. Alcohol separates it into, 2, a *basic salt*, $3 \text{KS}, \text{AsS}_3$, which precipitates as an oily liquid; it congeals by heat into a fibrous mass, deliquescent; and into, 3, the *bisulpharseniate*, KS, AsS_3 , known only in solution. A hyperacid salt, $\text{KS}, 12 \text{AsS}_3$, is obtained as a yellow powder by precipitating the neutral compound with carbonic acid.

Sulphar. of Soda. 1. *Neutral*. When dry, lemon-yellow, deliquescent, fuses in its combined water, which passes off. 2. The *basic salt* is obtained by precipitating the neutral with alcohol, or adding sulphhydrate of sodium to it and suffering it to evaporate spontaneously. The alcoholic precipitate consists of snowy,

crystalline scales, which crystallize in several forms. From a solution of AsS_5 in caustic soda they form irregular rhombic plates. From a solution of the alcoholic precipitate in boiling water it separates on cooling in long flat 6-sided prisms with acute angles, by spontaneous evaporation or slow cooling in 4-sided rhombic prisms terminated by 2 planes and by a still slower cooling below 32° in white opaque rhombic octahedra. They are permanent in the air, very soluble in water; lose their crystal-water by a gentle heat without change of form. Heated in a retort it fuses gradually, loses its crystal water, and finally, without decomposition, fuses to a dark red liquid, which is yellow on cooling, dissolves perfectly in water, after reassuming its crystal-water and becoming white. Form., $3\text{NaS}, \text{AsS}_5 + 15\text{aq.}$ 3. The bisulpharsenate, NaS, AsS_5 , obtained dissolved in alcohol, which, when distilled to a certain point, deposits crystalline scales of a super-sulphuret: 4. The yellow pulverulent super-salt is obtained like that of potassium. The double basic sulpharsenate of potassium and sodium crystallizes in colorless or slightly yellowish 4-sided plates.

The neutral salt of *lithium* is lemon-yellow, soluble; the acid and supersalts resemble those of potassium and sodium. The basic salt, $3\text{LS}, \text{AsS}_5$, formed like the corresponding salts of potassium and sodium, precipitates in large colorless crystalline scales, which, dissolved in water and rapidly cooled, crystallize in 6-sided prisms, by spontaneous evaporation, in 4-sided rhombic prisms. The sulpharsenates of *ammonium* are obtained similar to those of sodium and potassium; the neutral, $2\text{NH}_4\text{S}, \text{AsS}_5$, dries to a tough, gluey, yellow mass, with a slight decomposition; the basic, formed by mixing the neutral with sulphhydrate of ammonium, gently warming and shaking with hot alcohol, crystallizes on cooling in colorless prisms, which, by distillation, become the neutral salt; by distilling its solution it deposits the super-salt as a yellow powder: the acid salt remains dissolved in the alcohol. Sulphuret of arsenic, AsS_3 , absorbs ammoniacal gas, forming the sulpharsenate of *ammonia*, of a faint yellowish color, soluble in water, in which it soon decomposes. The double basic salt of *ammonium* and *sodium* obtained by mingling them together and shaking with warm alcohol, or by adding a suitable quantity of sal-ammoniac to a cold aqueous solution of the basic sodium-salt, crystallizes in clear, colorless, or slightly yellowish, 6 or 4-sided prisms, permanent in the air, very soluble in water.

The neutral salt of *barium* is soluble in every proportion in water, and, if dried, reassumes its crystal-water; the basic salt resembling the neutral, is obtained by heating the latter in a retort, or by mixing it with sulphuret of barium; or precipitating it with alcohol; evaporated and cooled in vacuo, the mixture, with sulphuret of barium, becomes crystalline; the acid salt is in the alcoholic solution and deposits a yellow powder by evaporation, which appears to be a sex-sulpharsenate. The neutral and basic salts of *strontium* and *calcium* closely resemble those of barium, but the basic are not

crystalline. The *magnesium* neutral salt is very soluble in water, and evaporates to a lemon-yellow mass with signs of crystallization; its solution is not precipitated by alcohol; the basic salt, formed by mingling the neutral with sulphhydrate of magnesium, as long as sulphuretted hydrogen is evolved, and evaporating in vacuo or cooling its concentrated solution to a low temperature, forms radiated, colorless, deliquescent crystals, from which alcohol extracts the neutral salt, leaving one still more basic: it forms a double basic salt with sulpharsenate of ammonium, which precipitates in crystalline needles from the alcoholic mixture. The salts of *glucinum* and *yttrium* are only known in solution. The *zirconium* salt is precipitated both by the neutral and basic potassium salt; it is lemon-yellow, becoming more orange in drying, and, like the sulphuret of zirconium, is not in the slightest degree attacked by acids.

The neutral and basic compounds of sulphuret of *cerium*, CeS , are yellow precipitates; the salt of sesquisulphuret, $2\text{Ce}_2\text{S}_3, 3\text{AsS}_5$, is somewhat soluble. The neutral salt of *manganese*, $2\text{MnS}, \text{AsS}_5$, is best obtained by digesting freshly precipitated and still moist sulphuret of manganese with water and sulphuret of arsenic, AsS_3 ; by evaporation leaves a lemon-yellow mass. If strong ammonia be poured over this neutral compound, it leaves a light red powder, the basic salt, $3\text{MnS}, \text{AsS}_5$. The salt of protosulphuret of *iron* is a brownish black precipitate, soluble with a similar color in an excess of the precipitant. The compound of sesquisulphuret of iron, $2\text{Fe}_2\text{S}_3, 3\text{AsS}_5$, is precipitated by the neutral salt of a dirty, grayish green color, which is the color of the liquid with an excess of the precipitant; the basic salt has a similar color: both salts keep on drying, becoming grayish green, and are extremely fusible. The salts of *cobalt* and *nickel* are dark-brown precipitates, becoming black, soluble in excess of the precipitant; the neutral and basic salts of *zinc* are bright orange-yellow precipitates, that of *cadmium* light yellow.

Neutral sulpharsenate of *lead* is dark brown, the basic bright red, both changing to black. The neutral and basic salts of protosulphuret of *tin* are chesnut-brown; those of bisulphuret orange-yellow. The salts of *bismuth* are dark brown, soluble in excess of the precipitant. The neutral and basic compounds of *uranium* are dark yellow, soluble in excess of the precipitant. Sulphar. of sulphuret of *copper*, $2\text{CuS}, \text{AsS}_5$, is dark brown, becoming black, and is often obtained in analysis, when sulphuretted hydrogen is passed through a solution containing copper and arsenic acid, this salt first separating, followed by the yellow sulphuret of arsenic. The salt of sulphuret of *mercury*, $2\text{Hg}_2\text{S}, \text{AsS}_5$, precipitates black, if the solution contained no red oxide, otherwise yellowish; by distillation, it decrepitates violently at a certain temperature, giving off mercury, when the following salt sublimes: the salt obtained by precipitation, $2\text{HgS}, \text{AsS}_5$, both neutral and basic, is dark yellow, the sublimed is black, shining, and has a red streak. The salt of *silver*, neutral and basic, is black,

fuses, without loss, to a shining, gray, metallic mass, which is soft and malleable, and calcines in the air, leaving sulphuret of silver. Sulphur. of bisulphuret of *iridium*, both neutral and basic, gives a dark-yellow solution, becoming dark brown, in which copperas produces a brownish black precipitate. The neutral compound of sesquisulphuret of *gold* is soluble in water, with a reddish brown color; the basic precipitates of a dark brown color, dissolves by washing on the filter, and precipitates yellowish brown with copperas. The neutral and basic sulpharseniate of *chrome* is a dirty yellow precipitate.

TESTING FOR ARSENIC.

The greater part of the following on arsenical tests is taken from the excellent essay on Analysis by Fresenius.

Odor. If arsenious or arsenic acid, or their salts, be exposed on a charcoal support to the *reducing flame of a blowpipe*, a highly characteristic odor of garlic will be perceived, especially if some carbonate of soda be added to the test specimen. This odor is owing to the reduction and reoxidation of the arsenic, and enables us to detect even minute quantities of this substance. This test, however, cannot be implicitly relied upon alone, but is very valuable in connection with others. The garlic odor belongs neither to the vapor of arsenious acid, nor to those of arsenic, but probably to a lower degree of oxidation of the latter substance. It is always perceived on exposing arsenic to heat, with the free access of air.

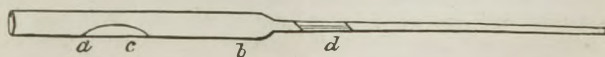
Crystalline form. If arsenious acid, or an arsenite mixed with boracic acid, be heated in the end of a narrow tube, drawn out and closed, it sublimes and condenses in small crystals, which, under a microscope, exhibit the triangular facets of the regular octahedron. When this is observed, in connection with other tests, it may be implicitly relied on.

Reduction. If either arsenical acid or its salt be mixed with *carbonate of soda and charcoal*, and the mixture (which must be perfectly dry) be then heated over a spirit-lamp to redness, in a well-dried glass tube, closed at one end, and drawn out into a point at the other, (Fig. 27,) the charcoal will oxidize at the expense of the oxygen of the arsenious acid, and arsenic will become liberated, which volatilizes and condenses above the heated part of the tube, forming a more or less dark-brown metallic mirror of great lustre. This crust may be further driven on in the tube by gradually heating the latter to redness towards its emission aperture, and may thus finally be expelled, when the characteristic odor of arsenic (on volatilizing in the air) will afford a further

proof of its presence. For the reduction of the free arsenious acid, a mere fragment of charcoal is used, instead of carbonate of soda and charcoal; the arsenious acid is introduced into the drawn-out point of the tube, the fragment of charcoal is placed over it and heated to redness; heat is then applied to the point of the tube. This process has the advantage over the former of not soiling the tube, which is done when operating with carbonate of soda and charcoal. The non-appearance of the metallic crust is not always a sure sign that no arsenic is present, when testing a supposed arseniate by means of carbonate of soda and charcoal, as there are several compounds of arsenious acid, especially of those with heavy metallic oxides, as e. g. oxide of iron, which do not yield metallic mirrors.

If either of the acids of arsenic, an arsenite, arseniate, or a sulphuret of arsenic be fused together with a mixture of dry carbonate of soda and cyanide of potassium, all the arsenic contained in the test specimen will become reduced, under all circumstances, and sometimes the bases also, if their properties admit of this reduction; in this process, the oxygen which these substances lose, converts a portion of the cyanide of potassium into cyanate of potash. The operation is conducted in the following manner:—the arsenic compound, which must be perfectly dry, is put into a small glass tube, expanded into a bulb at one end, and covered with six times its quantity of the mixture of perfectly dry carbonate of soda and cyanide of potassium. The quantity of the whole mass must not fill more than half of the bulb, or else the cyanide of potassium, when in fusion, will get into the tube. The heat of a spirit-lamp is then applied to the bulb, and continued, as the arsenic often requires some time for its complete sublimation. The mirrors which are obtained in this process are of exceeding purity. These crusts are produced from all arsenites, the bases of which remain either altogether unreduced or are converted into such arseniurets as partly or totally lose their arsenic on the simple application of heat. This method may be especially recommended on account of its simplicity, neatness, and cleanness, as well as for the certainty of its results, even though but minute quantities of arsenic be present. It is especially adapted for the direct production of arsenic from sulphuret of arsenic, and is in this respect superior to all other methods suggested. The most exact results are obtained by placing the sulphuret of arsenic, rubbed together with twelve times its amount of a mixture consisting of three parts of dry carbonate of potash, and one part of cyanide of potassium into a glass tube, open at its anterior extremity.

Fig. 27.



The mixture is best introduced into the tube by means of a slip of paper, folded into the shape of a gutter. This paper containing the mixture is inserted into the tube, and the latter then being turned half way round its axis, the

powder falls into it (at the spot *a c*) without soiling any other part. The tube is then gently heated in its entire length, transmitting, at the same time, a very slow stream of dry carbonic acid gas (dried by means of sulphuric acid)

through it, till all water is expelled. The spot *o* is then heated to a feeble degree of redness, when, as this point is attained, the mixture is heated from *a* towards *c*, by means of a second lamp. The arsenic condenses at *d*, forming a crust of admirable purity. In this manner the most distinct metallic mirrors may be obtained from one 260th part of a grain of sulphuret of arsenic and even less. (*Fresenius and Babo.*)

Precipitates. 1. *Arsenious acid.* Nitrate of silver produces, in neutral solutions of the arsenites, a yellow precipitate of *arsenite of silver* ($2 \text{ AgO}, \text{AsO}_3$), which is soluble both in dilute nitric acid and in ammonia. *Ammonio-nitrate of silver* yields the same precipitate with solutions of arsenious acid or arsenites when containing free acid. *Sulphate of copper* and *ammonio-sulphate of copper* produce, under the same circumstances as the salts of silver, yellow green precipitates of *arsenite of copper* ($2 \text{ CuO}, \text{AsO}_3$). If arsenious acid be dissolved in solution of caustic potash in excess, or if the solution of an alkaline arsenite be mixed with caustic potash, and a few drops of a dilute solution of sulphate of copper be added and the mixture boiled, a red precipitate of protoxide of copper is formed, and arseniate of potash remains in solution. This reaction is highly sensible, provided only a minute quantity of solution of blue vitriol be used. If the red precipitate of protoxide of copper is no longer distinctly visible on the light falling through the tube in which the solution is contained, it will yet be distinctly seen on looking in at the top of the tube. That this reaction, though really important in individual cases as a confirmatory test of arsenious acid, and especially as a means of distinguishing arsenious acid from arsenic acid, yet cannot be employed as a means of directly detecting the presence of arsenic, is a matter of course, since grape sugar and other organic substances in the same manner separate protoxide of copper from salts of copper.

2. *Arsenic acid.* Nitrate of silver produces, in neutral solutions of the arseniates, highly characteristic reddish-brown precipitates of *arseniate of silver* ($3 \text{ AgO}, \text{AsO}_5$), which is soluble both in dilute nitric acid and in ammonia. *Ammonio-nitrate of silver* yields the same precipitate with solutions of arsenic acid or arseniates. *Ammonio-sulphate of copper* produces, under the same circumstances as the salts of silver, greenish blue precipitates of *arseniate of copper* ($2 \text{ CuO}, \text{AsO}_5$).

If it had been ascertained that arsenic acid was present, it should be reduced to arsenious acid by mingling it with a solution of sulphurous acid and boiling off the excess of acid. This reduction is of some importance, in consequence of the much greater difficulty of precipitating sulphuret of arsenic from arsenic acid or an arseniate. (*Wöhler. Berz. Jahr., 1841, p. 89.*)

Sulphuret. Sulphuretted hydrogen precipitates the solutions of arsenious acid and of neutral arsenites, slowly and incompletely, but when a free acid is present, totally and immediately; these precipitates have a lively yellow color. Alkaline solutions are not precipitated. The yellow precipitate of sulpho-arsenious acid (AsS_3), is readily and completely redissolved

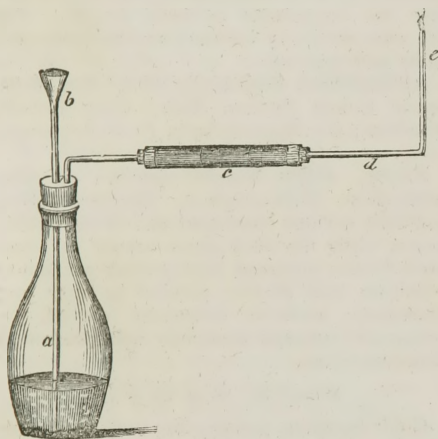
in pure alkalies, in alkaline carbonates and bicarbonates, and in alkaline sulphurets, but is almost insoluble in hydrochloric acid. Boiling nitric acid readily decomposes and dissolves it. On deflagrating it with carbonate of soda and nitrate of potash, arseniated alkali and sulphated alkali are obtained. When a solution of sulpharsenious acid in potash is boiled with oxide of copper, sulphuret of copper and arseniate of potash are formed; and when the same solution is boiled with pure oxide of bismuth, or with a carbonate or basic nitrate of the same substance, sulphuret of bismuth and arsenious acid are formed. If sulpharsenious acid be mixed with from three to four parts of carbonate of soda, with the addition of some water, and the magma be then spread over some small glass splinters, and the latter, after having been well dried, be rapidly heated to redness, in a glass tube, through which dry hydrogen gas is transmitted, half of the arsenic contained in the mixture forms a metallic mirror within the tube. (See *fig. 24*, under *ANALYSIS*, in which *ef* is a small tube thrust directly into the cork of the chloride of calcium tube, and without the enclosed tube *gh*.) For when fusing two eq. of sulpharsenious acid, together with 4 eq. of soda, sulpharsenico-sulphuret of sodium and arsenite of soda are formed; heating these products in hydrogen gas, all the arsenic is expelled, if the heat is strong and continuous. This method, although a great portion of the reduced arsenic is carried off, suspended in the hydrogen gas, yields, nevertheless, very good results. If the hydrogen gas be kindled at the exit aperture, *f*, of the tube, and a cold porcelain plate depressed on the flame, this arsenic (carried away with the hydrogen gas) will condense upon the plate. If a red heat be applied to another part of the tube, more towards its anterior aperture, (the part first heated being at the same time maintained at a red heat,) another sublimate will be formed beyond the heated spot, the particles of arsenic carried away with the stream of the hydrogen gas, being reconverted, at the red-hot spot, into arsenic vapors in a state of expansion, and thus condensing again as a sublimate, on coming into contact with the cold part of the glass tube. If the heat thus simultaneously applied to two parts of the tube be strong, whilst the stream of the hydrogen gas is feeble, scarcely any arsenic will be carried away with the gas. No arseniuretted hydrogen is formed in this operation, and those who explain the phenomena just described, by the formation of arseniuretted hydrogen, are in error. (*Fresenius and Babo.*) The apparatus may be constructed, as in *fig. 24*, with the alteration noted above.

a is the evolution flask, *d* a tube containing chloride of calcium, *ef* the tube in which, at the point *g*, the glass splinters with the specimen is placed. This part is then (the apparatus being completely filled with pure hydrogen gas) exposed to a slight heat, at first, in order to expel all moisture, and then suddenly to a very strong heat, (this is best done with a blow-pipe,) to prevent the sublimation of undecomposed sulphuret of arsenic. The metallic mirror is formed near the point *i*.

Hydrosulphuret of Ammonia causes also the formation of sulpharsenious acid. In neutral or alkaline solutions, however, this substance is not precipitated, but remains in solution as sulpharsenico-sulphuret of ammonia. On the addition of free acid it precipitates immediately from this solution.

Arseniuretted Hydrogen. If an acid or neutral solution of arsenious acid, or of an arsenite, be mixed with zinc, water, and sulphuric acid, arseniuretted hydrogen (AsH_3) will be formed. This property of arsenic affords us a most delicate test for its detection, and a highly important means for its isolation. The operation is conducted in the apparatus, Fig. 28.

Fig. 28.



a is the evolution flask, containing fragments of metallic zinc, and water, *b* a funnel tube, through which the sulphuric acid, and afterwards the liquor to be tested for arsenic, are poured into the flask, *c* is a glass tube, loosely filled with smooth cotton, to which a bent tube, *d*, is fitted by means of a perforated cork; this tube is drawn out into a point, at its emission extremity, *e*, and pinched off at the top. When the evolution of hydrogen has proceeded for some considerable time, so that it may safely be inferred that all atmospheric air has been expelled from the apparatus, the gas is kindled at the emission aperture of the tube, *d, e*. (It is advisable to envelope the flask with a piece of cloth before kindling the gas, as an effectual means of preventing any accident, should an explosion take place.) It is absolutely necessary to ascertain, first, whether the zinc and the sulphuric acid are quite free from arsenic. For this purpose, 1st, a porcelain plate is depressed upon the flame, and, 2d, the tube *d, e* is heated to redness in the middle, the limb *e* being turned into a horizontal position for this purpose. If no incrustation be formed, neither on the plate nor in the tube, the zinc and sulphuric acid contain no arsenic. The liquor to be tested is then introduced into the flask through the funnel tube. If it contain arsenic, arseniuretted hydrogen will be evolved together with the hydrogen, imparting a bluish tint to the flame, owing to the arsenic separating at a red heat. At the same time white fumes of arsenious acid are observed, which condense upon cold objects. If a porcelain plate be now depressed

upon the flame, black spots are formed on its surface, owing to the reduced and not yet reoxidized arsenic condensing on the plate. Arsenic spots are of a rather blackish brown colour, and bright metallic lustre; whilst those of antimony are of a deep black colour, and but very feebly lustrous. If the tube *d, e* be heated to redness in the middle of its limb *d*, the arsenic will condense in the cold part of the tube, forming a particularly beautiful and distinct metallic crust, which is of a darker appearance and less silvery than that formed by antimony under similar circumstances; it may, moreover, be clearly detected by the characteristic odour of garlic which is perceived, if the tube is cut off near the incrustation, and the latter then volatilized by heat. If the metallic spots of crust formed on the porcelain plate seem to indicate the presence of arsenic, it is still necessary to make quite sure that it is really arsenic and not antimony we have before us, for even the characteristic odour of garlic is not sufficient to set all doubts at rest as to this point. The following are the best methods of ascertaining the presence of arsenic beyond doubt:—

a. A fine and distinct metallic mirror is formed within the tube through which the arseniuretted hydrogen passes, on heating its middle part to redness. A very feeble stream of dry sulphuretted hydrogen is then transmitted through this tube, with simultaneous application of the heat of a spirit-lamp to the metallic crust, from its outer towards its inner extremity. If arsenic alone be present, a yellow sulphuret of arsenic will be formed within the tube; and if antimony alone be present, an orange or black sulphuret of antimony; but if both metals be present, both sulphurets will be formed side by side, the sulphuret of arsenic, as the more volatile, always preceding the sulphuret of antimony. Not long ago, this conversion of antimony and arsenic into sulphurets was suggested as the surest means of distinguishing these two metals from each other. Experience has, however, taught us that these differences in colour and volatility are not striking enough to prevent the possibility of mistakes. But if dry hydrochloric acid gas be transmitted through the tube containing the deposit under examination, without application of heat, no alteration whatever will take place if sulphuret of arsenic alone is present, even if the gas be transmitted through the tube for a considerable time. If sulphuret of antimony alone be present, it will entirely vanish, and if both sulphurets be present, the sulphuret of antimony will vanish immediately, whilst the yellow sulphuret of arsenic remains. If a small quantity of ammonia be then introduced into the tube, the sulphuret of arsenic will dissolve, and may thus easily be distinguished from the sulphur which peradventure may have separated.

b. The limb *e*, Fig. 28, is turned into an horizontal position, and the gas kindled and made to burn in a small glass receiver, having a capacity of about twelve ounces. This receiver is placed in a beaker glass filled with cold water, and constantly turned and moved, so as to prevent its becoming hot. After some time, when the oxygen in the receiver becomes

exhausted, and the flame grows feeble, another is substituted for the first, and several are filled in this manner. They contain, 1st, arsenious acid alone, or, 2d, oxide of antimony alone, or, 3d, both together. If the first be the case, the white sublimate obtained will completely dissolve in hot water, and the solution may then be further tested for arsenic. In the second case, nothing will dissolve, nor, in the third, if the oxide of antimony is present in sufficient quantity, as this gives rise to the formation of arsenite of antimony. The arsenic in this last case may be detected by dissolving the sublimate in slightly dilute solution of potash, and adding sulphuretted hydrogen first, and then bicarbonate of ammonia in excess. All the antimony will precipitate as sulphuret of antimony, whilst the sulphuret of arsenic remains dissolved in the excess of bicarbonate of ammonia. The sulphuret of arsenic precipitates on the addition of hydrochloric acid to the solution, till an acid reaction becomes manifest. Marsh was the first who suggested the method of detecting arsenic by the production of arseniuretted hydrogen.

Berzelius's Test. The method of employing Marsh's apparatus devised by Berzelius is deserving attention. Introduce into the middle of a glass tube of about $\frac{1}{16}$ inch diameter, a spirally-wound copper wire, containing a layer of 1 to $1\frac{1}{2}$ inches in length of oxide of copper, reduce it by pure hydrogen and draw a little air through it when cold and dry to remove this gas. Introduce zinc free from arsenic into flask *a*, Fig. 28, connect it with the tube *c*, then pour in a little sulphuric acid (also free from arsenic) through the tube *b*, and when all the atmospheric air is expelled, connect with the apparatus the tube containing copper, in place of the tube *d*, Fig. 28, and bring the copper to ignition; lastly, pour through *b* the arsenical liquid to be tested. The evolution of hydrogen should be slow, and when it diminishes may be increased by more sulphuric acid. After the operation is complete, the front part of the copper is silver-white from arseniuret of copper, and if the tube, with the copper, had been previously weighed, the now increase in weight is arsenic. A small portion of the arseniuret tested by the blowpipe gives the then infallible test in the characteristic arsenical odor. In order to remove the copper, digest with chloride of copper and muriatic acid and wash out the dichloride of copper from the undissolved arseniuret by muriatic acid. If antimony were present, it is also absorbed by the copper, but the arsenical odor can be perceived at once, particularly by adding a little soda or borax. (*Berz. Lehrb.* x. p. 203. 1841.)

Reinsch's method appears to be an excellent one and may be often employed. Add much muriatic acid to the arsenical liquid, introduce a clean strip of copper, and heat, but not to boiling. The copper is coated with arsenic in 8—10 minutes, and looks like iron. The test is sufficiently delicate to show arsenic in the course of a $\frac{1}{2}$ hour, when the liquid contains only $\frac{1}{2000000}$. By leaving the copper for some time in the warm liquid the arsenic falls off,

and may be tested by its odor, or if the quantity were too small, the coating on the strip is moistened with a little nitric acid, which dissolves the arsenic, and the solution may then be tested by a small Marsh's apparatus. An equally small quantity of antimony is detected in this manner, but the odor or appearance of this and other metals thrown down by copper will serve to distinguish them from arsenic with certainty. (*Berz. Jahresb.* xxii. 174. 1842.)

ARSENIC GLANCE. *Min.* An analysis by Berzelius gives the formula As_8S_8 , which is the same with the artificial black sulphuret described under ARSENIC. Kersten's analysis of a mineral called arsenic glance gave arsenic 96.785 + bismuth 3.001 = 99.786, which would give the improbable formula, $As_{30}Bi$. The two were evidently different, and the latter probably native arsenic.

ARSENICAL COBALT. *Min.* Syn. Octahedral Cobalt Pyrites, *Mohs*; Gray Cobalt; Smaltine; *Ger.* Speisskobalt; *Fr. C.* Arsenical. *Hämy*.

Descrip. Cryst. Regular system; as cube, octahedron, dodecahedron, ikositetrahedron and their various combinations; in homoedric forms, while the *cobalt glance* occurs in hemiedric forms; cleavage most perfect parallel to 8-hedron, less perfect parallel to cube and 12-hedron; surfaces frequently curved. It occurs also amorphous in botryoidal and other imitative forms.

H. = 5.5. G. = 6.4 — 7.

Color tin-white, passing into steel-gray, when massive; lustre metallic, glistening; streak grayish black; brittle, fracture uneven, fine granular.

Behavior. In a closed tube nothing sublimes; in an open tube crystals of arsenious acid sublime; on charcoal it gives off arsenical fumes, fusing to a white globule, which is brittle, and gives a blue glass with borax and mic. salt. Readily dissolved by nitric acid, forming a red solution with the separation of arsenious acid.

Analysis. 1. The cryst. from Riechelsdorf by Stromeyer; 2. amorphous, from Schneeberg by Hofmann; 3. amorphous, from Tunaberg by Varrentrapp.

	1.	2.	3.
Arsenic.....	74.21	70.37	69.459
Cobalt.....	20.31	13.95	23.440
Iron.....	3.42	11.71	4.945
Nickel.....	—	1.79	—
Copper.....	0.16	1.39	—
Bismuth.....	—	0.01	—
Sulphur.....	0.88	0.66	0.900
	98.98	99.88	98.744

Formula, $CoAs$, in which a portion of the cobalt is replaced by iron and other metals.

Berzelius observed that it sometimes yielded a sublimate of arsenic in a closed tube, and hence supposed it might contain Co_2As_3 . The following analysis of arsenical cobalt from Skutterud confirm his view. 1. By Scheerer; 2. a crystallized, and, 3. an amorphous specimen by Wöhler.

ARSENICAL COBALT.

	1.	2.	3.
Arsenic	77.84	79.2	79.0
Cobalt	20.01	18.5	19.5
Iron	1.51	1.3	1.4
Sulphur	0.69	—	—
	100.05	99.0	99.9

It is therefore Co_2As_3 , and Scheerer proposed to call it Arseniocobalt Pyrites.

Locality. Associated with cobalt glance, copper-nickel, &c. At Schneeberg, Freyberg, Annaberg, Saxony; Joachimsthal, Bohemia, the reticulated form frequently found in calc spar; in heavy spar, in the copper-slate formation at Riechelsdorf, Hessia; Huel Sparnon, Cornwall. The sesquiarseniuret, Co_2As_3 , occurs at Skutterud mine, Norway.

Use. This ore and the cobalt glance afford nearly all the cobalt used in the manufacture of smalt and the blue pigments employed for

ARSENICAL NICKEL

painting on enamel, porcelain, and other clay-wares. See COBALT.

ARSENICAL IRON. *Min.* Syn. Axotomous arsenical pyrites, *Mohs.* Leucopyrite, *Dana.*

Descrip. Right rhombic prism of $122^\circ 26'$, the terminal planes with each other $= 51^\circ 20'$; generally massive. Cleaves perpendicular to the axis. $H. = 5 - 5.5$. $G. = 7.1 - 7.4$. Color silver-white; steel-gray; lustre metallic; streak grayish black; brittle; fracture uneven.

Behavior. Evolves strong arsenical odors on charcoal, becoming a black magnetic mass; sublimes metallic arsenic in a closed tube; dissolves in nitric acid with the separation of arsenious acid.

Analysis. From Reichenstein, Silesia, 1. by Hoffmann; 2. by Meyer; 3. by Kersten; 4. from Schlading, Styria, by Hoffmann; and, 5 and 6. from Fossum, Norway, by Scheerer.

	1.	2.	3.	4.	5.	6.
Sulphur	1.94	1.631	1.77	5.20	1.33	1.28
Arsenic	65.99	63.142	65.88	60.41	70.09	70.22
Iron	28.06	30.243	32.35	13.49	27.39	23.14
Serpentine	2.17	3.550	—	Nickel 13.37	—	—
	—	—	—	Cobalt 5.10	—	—
	98.16	98.566	100	97.57	98.81	99.64

Formula, FeAs . It would therefore resemble arsenical nickel in composition (see below), the iron being replaced by nickel, but its crystalline form, if well ascertained, is different. A portion of iron is replaced by nickel and cobalt in the mineral from Schlading, and, if the sulphur be calculated as FeS , the formula is $(\text{Fe}, \text{Ni}, \text{Co}) + \text{As}$, and its composition approximating so closely to that of the arsenical nickel, it should have the same crystalline form. Scheerer proposes, for the present, to call the mineral from Reichenstein (Fe_2As_3) arsenical iron in minimum, and that from Fossum in maximum; for if the sulphur be abstracted as arsenical pyrites (see below) the remainder would have the formula, Fe_2As_3 .

Locality. Associated with copper-nickel at Schlading in Styria; in serpentine at Reichenstein, Silesia; in Sperry iron ore with bismuth and scorodite at Löling near Huttenberg in Carinthia; from Sättersberg near Fossum, Norway.

The arsenical iron from Bedford county, Pennsylvania, analyzed by C. Shepard, containing iron 97.05 + arsenic 1.55 + graphite 0.40 = 99, is probably native iron containing a small quantity of arsenic.

ARSENICAL MANGANESE. *Min.* Syn. Arseniuret, Arsenide, Arseniet of M.

Descrip. Massive and botryoidal, of a granu-

lar or foliated structure, grayish white color, metallic lustre, and uneven fracture; hard. $G. = 5.55$.

Behavior. Tarnishes with a black powder in the air; before the blowpipe, it burns with a blue flame, gives off arsenical fumes, coating the charcoal white; wholly soluble in aqua regia, with difficulty in nitric acid.

Analysis by Kane, manganese 45.5 + arsenic 51.8 + iron 2.70 = 100. Formula, Mn_2As . (?) Found in Saxony, associated with Galena.

ARSENICAL NICKEL. Syn. Binarseniuret of N., White N.

Descrip. Cryst. Regular system, consisting of the cube combined with 8-hedron and 12-hedron; it is generally columnar and massive. Color tin-white, with faint lead-tint; lustre metallic, shining on the crystalline planes, otherwise glimmering; fracture uneven.

Behavior. In an open tube it yields arsenious acid, in a closed tube metallic arsenic sublimes; on charcoal gives arsenical fumes, fusing to a yellowish globule of kupfernickel; with borax it gives the blue cobalt glass, and if this be broken off and again treated with borax, the remaining globule in mic. salt gives the reaction of nickel, a reddish brown bead.

Analysis. 1. From Schneeberg by Hoffmann, 2. from Riechelsdorf by Booth; 3. from Tanne by Hoffmann; 4. from Sitten by Berthier.

	1.	2.	3.	4.
Arsenic	71.30	72.64	53.60	65.02
Nickel	28.14	20.74	30.02	26.75
Bismuth	2.19	Cobalt 3.37	0.56	3.93
Copper	0.50	Iron 3.25	3.29	1.40
Sulphur	0.14	—	11.05	2.90
	102.27	100.00	98.52	100.00

ARSENICAL PYRITES.

Formula, (Co, Fe) NiAs, or more simply, NiAs. (See ARSENICAL IRON above.) If the sulphuret of nickel, NiS, be abstracted from the 3d, and nickel glance from the 4th, they correspond more closely with the formula.

Locality. Schneeberg, Saxony; Tanne, in the Harz; Riechelsdorf, Hessia.

ARSENICAL ORES.

Arsenic	As
Arsenious acid.....	AsO ₃
Arsenic glance.....	As ₂ S
Realgar.....	As ₂ S ₂
Orpiment.....	As ₂ S ₃
Arsenical cobalt	Co ₂ As ₃
“ “	CoAs
Arsenical iron.....	FeAs
Arsenical nickel.....	NiAs
Copper-nickel.....	Ni ₂ As
Arsenical manganese.	Mn ₂ As
Arsenical pyrites....	FeS ₂ + FeAs
Cobalt glance.....	CoS ₂ + CoAs
Nickel glance.....	NiS ₂ + NiAs
Ruby silver (light)...	3 AgS + AsS ₃

See also, GRAY COPPER, POLYBASITE, and ANTIMONIAL ORES.

Minerals containing salts of the arsenical acids are not generally included under the ores.

ARSENICAL PYRITES. *Min.* Syn. Mispickel, Marcasite; Prismatic Arsenical Pyrites, *Mohs.* *Ger.* Arsenikkies. *Fr.* Fer arsenical.

Descrip. Cryst. Right rhombic system. The prevailing forms are the vertical rhombic

	1.	2.	3.	4.
Arsenic..	42·88	45·74	43·418	47·55
Sulphur..	21·08	19·60	20·132	17·57
Iron	36·04	33·98	34·938	26·54
Cobalt...	—	—	—	8·31
	100	99·32	98·488	99·97

The 8th contained 1·01 of foreign matter, making the total = 99·68. Formula, FeS₂ × FeAs (FeS₂ + FeAs₂, *Berz.*); or for those in which a portion of iron is replaced by cobalt (Co) FeS₂ + (Co) FeAs.

Jordan analyzed an arsenical pyrites from Andreasberg, and found it to contain

Arsenic	55·000
Sulphur	8·344
Iron.....	36·437
Silver.....	0·011
	99·792

for which he proposed the formula FeS₂ + Fe₂As₃.

Locality. It is generally in primary rocks. It occurs at Freiberg, Munzig; Ehrenfriedersdorf, Altenberg, in Saxony; Raschau, Breitenbrunn; Andreasberg, on Harz; Schlackenwald, Joachimsthal in Bohemia; Schladming, Styria; Reichenstein, Kupferberg, in Silesia; Salathna, Transylvania; Tunaberg, &c., Sweden; Skutterud, near Modum, Norway; Wheal Maudlin, &c., Cornwall, England. In the United States, well crystallized, at Franconia, N. Hampshire; Worcester, Massachusetts; Chatham, Connecticut, with arsenical cobalt and copper-nickel;

ARSENIOPHOSPHATES.

prism, with an angle of 111° 53', terminal plane, several horizontal prisms of one order, and a hor. prism of the 2d order; cleaves parallel to vertical prism, on the planes of which crystals sometimes combine. Crystal-line, columnar, fine granular.

H. = 5·5 — 6. G. = 5·7 — 6·2.

Color silver-white, passing into steel-gray, and sometimes with a yellowish tint; lustre metallic; streak dark iron-gray; brittle with uneven fracture.

Behavior. In a closed tube it gives first a red, then a brown sublimate of sulphuret of arsenic, then metallic arsenic as a shining, gray, metallic, crystalline mass; in an open tube yields also sulphurous and arsenious acids; after expelling arsenic on charcoal there remains a black magnetic globule which behaves like magnetic pyrites; cobalt may be often detected in the calcined test. According to Berthier, it loses $\frac{1}{2}$ of its sulphur and $\frac{3}{4}$ of its arsenic by fusion. Rapidly acted on by nitric and nitromuriatic acid, with the separation of sulphur and arsenious acid, which dissolve after some time.

Analysis. 1. Cryst. from Freiberg by Stromeyer; 2. from Sweden by Thompson; 3. by Chevreul; cobalt-arsenical pyrites from Skutterud, Norway, 4, 5, 6. by Scheerer; 7. by Wöhler; 8. from Franconia, New Hampshire, U. S., by Hayes; 9. the theoretical composition, according to Berzelius.

	5.	6.	7.	8.	9.
Arsenic..	46·76	46·01	47·45	41·44	46·53
Sulphur..	17·34	18·06	17·48	17·84	19·90
Iron	26·36	26·97	30·91	32·94	33·57
Cobalt...	9·01	8·38	4·75	6·45	—
	99·47	99·42	100·59	98·67	100

Monroe, Connecticut, with wolfram, magnetic pyrites, and bismuth; at Amity, New York, in limestone, with arragonite.

ARSENICAL SILVER. *Min.* Found at Andreasberg, on Harz, and in other localities; a specimen from Andreasberg yielded Klaproth arsenic 35, antimony 4, silver 12·75, iron 44·25. It is apparently a mixture and not a simple mineral. (*Rammelsberg.*)

ARSENIUS ACID. *Min.* *Ger.* Arsenikblüthe. *Descrip.* Rarely crystallized in regular octahedron, generally fibrous, radiated, botryoidal, stalactitic. H. = 1·5. G. = 3·698. Color white, with an occasional reddish or yellowish tint; lustre vitreous, silky; transparent, opaque; taste faintly sweetish, metallic.

Behavior. Sublimes entirely in a closed tube, condensing in brilliant octahedra; mingled with charcoal, sublimes black, shining, metallic arsenic, which volatilizes with the peculiar arsenical odor; soluble in water and acids. For its composition and other properties, see *Arsenious acid* under ARSENIC.

Locality. It accompanies arsenical ores from which it is derived by oxidation, at Andreasberg on the Harz; Joachimsthal in Bohemia; Kapnick in Hungary, &c.

ARSENIOPHOSPHATES. *Min.* The well-known isomorphous character of phosphoric

ARSENIOSIDERITE.

and arsenic acids is exhibited in several mineral species, the formula for which will be here given, in order to afford a general view of them, while their descriptions, &c., will be presented in the proper places in the work.

Arseniophosphates of Lead. Arsenic sometimes replaces the phosphoric acid more or less, lime replaces oxide of lead and fluoride of calcium replaces chloride of lead.

Pyromorphite $\text{PbCl} + 3(3\text{PbO}, \text{PO}_5)$.

Mimetesite .. $\text{PbCl} + 3\left(3\text{PbO}, \begin{Bmatrix} \text{PO}_5 \\ \text{AsO}_5 \end{Bmatrix}\right)$

Hedyphane.. $\text{PbCl} + 3\left(\begin{Bmatrix} 3\text{PbO} \\ 3\text{CaO} \end{Bmatrix}, \begin{Bmatrix} \text{PO}_5 \\ \text{AsO}_5 \end{Bmatrix}\right)$

Nussierite... $\text{PbCl} + 5\left(\begin{Bmatrix} 3\text{PbO} \\ 3\text{CaO} \\ 3\text{FeO} \end{Bmatrix}, \begin{Bmatrix} \text{PO}_5 \\ \text{AsO}_5 \end{Bmatrix}\right)$

Iolyphærite $\begin{Bmatrix} \text{PbCl} \\ \text{CaF} \end{Bmatrix} + 3\left(\begin{Bmatrix} 3\text{PbO} \\ 3\text{CaO} \end{Bmatrix}, \begin{Bmatrix} \text{PO}_5 \\ \text{AsO}_5 \end{Bmatrix}\right)$

See also Apatite, which is closely allied to polysphærite.

Arseniophosphates of Copper. In these the acids are generally separate, but Olivenite and Liroconite contain both; Copper-froth contains carbonate of lime, which seems to be a uniform constituent.

Phosphates.	Arsenates.	Olivenite.....	$4\text{CuO} \begin{Bmatrix} \text{AsO}_5 \\ \text{PO}_5 \end{Bmatrix} + \text{HO}.$
		Euchroite.....	$4\text{CuO}, \text{AsO}_5 + 8\text{HO}.$
		Erinite.....	$5\text{CuO}, \text{AsO}_5 + 2\text{HO}.$
		Copper-froth....	$5\text{CuO}, \text{AsO}_5 + 10\text{HO}.$
		Copper-mica.....	$8\text{CuO}, \text{AsO}_5 + 12\text{HO}.$
		Liroconite (similar to Euchroite?)	
	Phosphates.	Aphanesite, composition uncertain.	
		Libethenite.....	$4\text{CuO}, \text{PO}_5 + 2\text{HO}.$
		Phosphorochalcite	$6\text{CuO}, \text{PO}_5 + 6\text{HO}.$
		"	$6\text{CuO}, \text{PO}_5 + 3\text{HO}.$
		Thrombolite.....	$3\text{CuO}, 2\text{PO}_5 + 6\text{HO}(!)$

ARSENIOSIDERITE. *Min.* Fibrous concretions; H. = 1. G. = 3.52; color brownish yellow, by exposure to air becoming darker; readily fusible before the blowpipe, giving the reactions of arsenic and iron. Analysis by Dufresnoy.

	Oxygen.
Arsenic acid.....	34.26
Peroxide of iron.....	41.31
Perox. of manganese..	1.29
Lime.....	8.43
Silicic acid.....	4.04
Potassa.....	0.76
Water.....	8.75

Omitting the silica, which M. Dufresnoy regards as a foreign ingredient, we have the formula $4\text{Fe}_2\text{O}_3, \text{AsO}_5 + 2\text{CaO}, \text{AsO}_5 + 6\text{HO}$, or $2\text{Fe}_2\text{O}_3, \text{AsO}_5 + 2\text{CaO}, \text{AsO}_5 + 2(\text{Fe}_2\text{O}_3, 3\text{HO})$. Its locality is a manganese mine at Romanèche near Mâcon.

ARSENITE. *Chem.* A salt of arsenious acid. See ARSENIC.

ARSENIURET, ARSENIDE, ARSENIET. A binary compound of arsenic with an element.

ARTEMISIA. *Phar.* A genus of plants containing several species employed medicinally. See WORMSEED and WORMWOOD.

ARTERY. *Anat.* The middle of the arterial coats, which is most characteristic of the arteries, loses, by drying, but little water, becoming dark brownish yellow, and even black,

ASAFÆTIDA.

hard and brittle; but, when softened in water, reassumes its previous appearance and elasticity; it resists putrefaction more than most animal solids. It is insoluble in water, and may even be boiled in it for several hours without solution; but if boiled for several days, it is decomposed, and a gelatinous substance extracted. (See GELATIN.) It is neither softened nor dissolved by concentrated acetic acid, and is insoluble in boiling dilute acid. It is very soluble by digestion with dilute sulphuric, nitric, and muriatic acids, and the solution is precipitated neither by alkali nor ferrocyanide of potassium. It is dissolved by caustic potassa to a colorless muddy liquid not precipitable by acids, but if the saturated alkaline be mingled with the saturated acid solution, a portion of the material is precipitated. It is entirely distinct from fibrin and muscular fibre.

ARTHANITIN. A peculiar crystalline substance found by Saladin in the root of the *Cyclamen Europæum*. Buchner and Herberger prepared it by freeing the alcoholic extract of the root from wax by ether, and from another substance by water; the residue was dissolved in boiling water, filtered, evaporated to an extract and treated with absolute alcohol, which extracted the arthanitin; by treatment with bone-black and spontaneous evaporation, it crystallized in a granular form. It is colorless, requires 500 water for solution, is very soluble in alcohol, not in ether, fixed nor volatile oils; its solution will not bear boiling; vegetable acids dissolve it more readily than water; the taste of the alcoholic solution is bitter and sharp; it reacts neutral, and is entirely precipitated by infusion of galls; sulphuric acid colors it red, nitric acid changes it into oxalic acid. Besides this substance, the root contains gum, starch, albumen, resinous bitter extractive, waxy fat, chloride of sodium, and salts of lime and potassa, with malic and sulphuric acids.

ASAFÆTIDA. *Phar. Ger.* Stinkasant, Teufelsdreck (*Stercus Diaboli*); some older writers termed it *Cibus Deorum*. It is a gum-resin derived from incisions made in the upper part of the root of the *Ferula Asafetida*; growing among the mountains of Chorasán and Laar in Persia. It is light yellow, becoming darker by age; and consists of agglutinated tears or masses. It has a strong, and to many persons, a disagreeable odor and taste. H. = 0.5. G. = 1.327. Becomes softer in the hands; burns with a clear flame; imperfectly soluble in water, forming a milky emulsion; best dissolved by alcohol containing acid or alkali. Brandes analysis of the gum-resin, gave resin 48.85, volatile oil 4.6, gum 19.4, traces of potassa and lime salts, with sulphuric, phosphoric, acetic, and malic acids, bassorin 6.4, extractive with acetate and malate potassa 1.4, malate of lime 0.4, sulphate of lime, with traces of sulphate of potassa, 6.2, carbonate of lime 3.5, oxide of iron and alumina 0.4, water 6.0, foreign admixture of sand and vegetable fibre 4.6.

The volatile oil, which gives the characteristic odor to the gum-resin, is obtained by distilling the latter with water or alcohol; it is very vola-

tile, lighter than water, at first clear and colorless, acquiring a yellow tint by exposure to the air; taste at first mild, then bitter and acid; soluble in every proportion in alcohol and ether, but requires 2,000 pts. water for solution. It contains sulphur.

Resin of Asafætida. The resinous matter of asafætida is soluble in alcohol. When the alcoholic solution is mixed with water, a milky fluid is formed, owing to the deposition of the *hydrated resin*. Oil of turpentine and the oil of almonds also dissolve the resin, but less readily than alcohol. The resin obtained by evaporating the alcoholic solution, consists, according to Johnson, of $C_{40}H_{26}O_{10}$. By exposure to the sun's rays it becomes violet red. Brandes has shown that the resin of asafætida is of two kinds; one insoluble in ether, the other soluble. The proportion of the first to the second is as 1.6 to 47.25.

1. *Resin insoluble in Ether.* Is brownish yellow, brittle, tasteless, has a slight allaceous odor, is fusible, and soluble in warm caustic potash.

2. *Resin soluble in Ether.* Is greenish brown, brittle, has an aromatic odor, and a faint, but permanent, alliaceous bitter taste. Chlorine decolorizes it. Cold oil of vitriol renders it dark red: if heat be applied, sulphurous acid is evolved, and the mixture becomes black: if the liquid be diluted with water, and saturated with an alkali, the surface assumes a sky-blue color. Nitric acid renders it first orange, then yellow, and makes it almost insoluble in ether. Hydrochloric acid dissolves it, and colors it pale red. It dissolves in boiling concentrated acetic acid, but is deposited when the solution cools.

Use. Besides its usefulness in medicine, it is employed among oriental nations (in Persia, &c.) as a condiment, either alone, or to flavor sauces and other food. The green leaves of the plant, as well as the roasted roots, are eaten.

ASARUM. Phar. The *Asarum Europæum* (common Asarabacca), has been used in medicine from ancient times. Gräger's analyses of the fresh root (*Ger. Haselwurz*) and the fresh herb are the best.

	Root.	Herb.
Starch.....	2.048	—
Bassorin	0.974	—
Albumen	0.036	2.12
Extractive.....	3.972	5.49
Tannin	1.072	0.04
Asarin	1.172	0.10
Volatile oil, with Asarin	0.630	—
Resin	0.156	—
Chlorophyll.....	—	1.52
Citric acid.....	0.316	0.54
Citrate of potassa.....	0.942	—
Citrate of lime.....	1.502	—
Citrate of magnesia....	0.118	—
Chloride of potassium..	0.117	—
Sulphate of potassa....	1.090	—
Phosphates.....	0.254	—
Ligneous fibre.....	12.800	15.00
Water.....	74.600	74.84
Loss	—	0.35
	100.709	100.00

Asarin. Obtained by distilling the dry root with 8 pts. water until 3 pts. have passed over; it crystallizes in the neck of the retort and in the receiver. The crystals are transparent, pearly, 4-sided plates, with an aromatic, camphor-like odor and taste; $G. = 0.95$; fuses at 158° , volatilizes entirely with irritating fumes. (*Gräger.*) It fuses at 104° and congeals at 80.6° ; it boils at 536° , but its temperature rises rapidly to 572° , when it is decomposed without sublimation. (*Blanchet and Sell.*) Difficultly soluble in water, very soluble in alcohol, from which water precipitates it in cubes and 6-sided prisms; dissolved by sulphuric acid, from which water again throws it down at first, but after a short time it browns and is no longer precipitable; if the brown solution be heated it becomes blue, and by the addition of water passes through violet and wine-red, and a humic substance precipitates; nitric acid changes it into a tough resin, dissolving one part with a yellow color. Blanchet and Sel's analysis leads to the formula, $C_{16}H_{11}O_4$. They believe that it is a compound of volatile oil with water, and obtained an oil by extracting the root with alcohol, which, when pure, gave the formula $C_{16}H_9O_2$; but the important variation between the percentage composition, as found by experiment and by calculation, excludes such an assumption.

Asarum-bitter. Precipitate the aqueous infusion of the root with acetate of lead, remove the lead by sulphuretted hydrogen, filter, evaporate to a syrup, treat with alcohol filter and evaporate. Yellowish brown, bitter, and nauseating to the taste, equally soluble in alcohol and water, precipitable by galls-infusion and subacetate of lead, but not by sugar of lead.

ASBESTUS. Min. Various minerals included under the name asbestos have been shown to belong to entirely different species, and, as Breithaupt has remarked, the term asbestos may rather be employed to denote a peculiar fibrous state into which many minerals pass. See MOUNTAIN WOOD, OPAL-ASBESTUS, PICROSIMINE, FIEROLITE. The greater part, however, seem allied to HORNBLÉNDE.

ASBOLIN. See SOOR.

ASCLEPIAS. Bot. A few species of this genus are employed, but rarely, in medicine. Feneulle found in the root of the *A. Vincetoxicum*, a peculiar emetic principle (not Emetin), resin, a waxy oil, gum, starch, traces of volatile oil, pectic acid, fibre, and salts of lime and potassa, with malic acid and oxalate of lime. To prepare the emetic principle, precipitate the decoction of the root by acetate of lead, filter, precipitate the lead by sulphuretted hydrogen, evaporate to extract, treat with alcohol, which extracts the emetic principle and resin, evaporate and extract by water; by repeating the latter operation, it is obtained free from resin. It is pale yellow, soluble in every proportion in water, alcohol, and alcoholic ether; it has no basic properties, contains no nitrogen; a dose of 3 grains produces vomiting; its aqueous solution is precipitated by basic acetate of lead, corrosive sublimate, and slowly by galls-infusion.

ASHES. Tech. Veget. Phys. Ger. Äsche, Fr. Cendres. The solid organic residue of

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organic substances after burning off the volatile and carbonaceous matters in the open air. It is more especially applied to the organic residues of plants, with reference to its use in the arts, and in this light we shall view it. The general constituents are potassa, soda, lime, magnesia, oxides of iron and manganese with silicic, carbonic, phosphoric, sulphuric acid

	Name of the substance reduced to ashes.	100 pts. of the soluble contain										100 pts. insoluble contain										Calcul. of Phosphates.	
		One pt. ashes contains		Acids.				Bases.		Water.	Acids.				Bases.				Carbon.				
		Soluble in water.	Insoluble in water.	Carbonic.	Sulphuric.	Muriatic.	Silicic.	Potassa.	Soda.			Carbonic.	Phosphoric.	Silicic.	Lime.	Magnesia.	Oxide of Iron.	Ox. Mangan.			Phosphate of Lime.	Phosphate of Iron.	
1	Beech-wood charcoal	3.0	0.155	0.845	22.4	7.5	5.2	1.0	64.1	—	32.9	5.7	5.8	42.6	7.0	1.5	4.5	—	1.7	3.75			
2	Oak-wood	2.5	0.120	0.880	24.0	8.1	0.1	0.2	67.6	—	39.6	0.8	3.8	54.8	6.0	—	7.4	—	1.8	—			
3	Oak-bark	6.0	0.050	0.950	23.2	6.0	0.7	0.8	69.3	—	38.5	—	1.1	50.1	5.1	0.8	—	2.1	—	—			
4	Linden-wood	5.0	0.108	0.892	27.42	7.53	1.80	1.61	60.64	—	39.8	2.8	2.0	51.8	2.2	0.1	0.6	—	5.4	2.5			
5	Birch-wood	1.0	0.160	0.840	17.0	2.3	0.2	1.0	79.5	—	31.0	4.3	5.5	52.2	3.0	0.5	3.5	—	7.3	1.25			
6	Alder-wood	0.188	0.812	—	—	6.6	0.3	—	—	—	31	7.7	5.0	50.2	2.5	3.6	—	—	3.45	9.0			
7	Fir-wood	0.83	0.500	0.500	13.5	6.9	0.0	2.0	28.2	41.5	21.5	1.8	13.0	27.2	8.7	22.3	5.5	—	—	—			
8	Fir charcoal	0.257	0.743	30.2	3.1	0.3	1.0	—	65.4	—	23.0	4.2	8.0	39.8	4.4	14.1	6.0	—	—	3.0			
9	Pine charcoal	10.24	0.136	0.864	20.75	12	6.6	1.33	31.66	51.33	36.0	4.2	4.6	42.3	10.5	0.1	0.4	4.8	1.72	6.3			
10	Wheat straw	4.4	0.190	0.810	Trace	0.2	13.0	35.0	50	—	—	1.2	75.0	5.8	—	2.5	—	15.5	—	0.25			

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chlorohydric acids. Alumina is rare, and traces of copper have been observed. A portion of ashes is soluble, consisting of carbonate, silicate, sulphate and muriate of potassa and soda, and a portion insoluble, consisting of silicate, carbonate and phosphate of lime and the other bases. Carbonate of lime constitutes one-half or more of these substances. The quantity of ashes varies according to the nature of the plant, its parts, its age, the nature of the soil, and even in the same plant the nature of the ingredients may vary under different circumstances. The foregoing table is extracted from Berthier's excellent researches on ashes. (*Berz. Lehrb.* viii. 764. See also Berthier, "Essais, p. l. voie seche." i. 259, &c., for a more complete view.)

No. 7 is the *Pinus Abies*. No. 9 *Pinus Sylvestris*. The carbonates are formed from the destruction of the organic acid with which their bases were united in the living plant. The experiments of Berthier also show the varying composition in different parts of the same plant, for while the wood of the larger branches of oak (2) give $2\frac{1}{2}$ per cent. ashes with $\frac{1}{4}$ of its weight of alkaline salts, the bark of the oak (3) yielded 6 per cent. ashes with only $\frac{1}{20}$ of soluble salts, while the insoluble portion contains much manganese. The ashes of wheat straw consist chiefly of silicate of potassa $3\text{ KO} + 2\text{ SiO}_2$, while the ashes of the grain consist mainly of phosphates of lime and magnesia. It is concluded from the analyses of Saussure and Berthier, that the nature of the soil exercises a marked influence on the quantity of the bases in the plant. Hence Liebig endeavors to prove that the equivalent quantity of fixed bases must be invariable in the same plant. See p. 74, under AGRICULTURE, in the present work.

The table on the following page, giving the composition of the ashes of a few plants, is drawn from an essay by C. Hertwig, in *An. d. Ch. und Phar.* xli. 97-117, (1843.) Comparing 3 and 4, the bark of beech yielded twice as much soluble and 25 times as much insoluble matter as the wood; it also contains of carbonate of lime 24, of magnesia 23, of phosphate of lime 15, of phosphate of magnesia 4, and of silica 69 times as much as an equal weight of wood; the basic phosphates of iron and alumina are nearly equal. Comparing 8 and 10, the soluble is 8 and the insoluble 4 times as much in the leaves as in the wood of the fir; the phosphates are more than 21, magnesia 3, silica 4 times as great, and the carbonate of lime nearly equal; the phosphates in the bark (9) are about 2, the carbonate of lime and the silica each 7 times as great as in the wood. In 11, 1600 lbs. of the leaves (dried at 212°) contain about 100 lbs. ashes, so that the same line (11) gives the composition in lbs. from 1600 lbs. of the leaves. Although the soluble and insoluble in 12 and 13 are respectively equal, the difference in the character of the soluble salts is very striking. There is also a marked difference in the soluble and insoluble salts of the plant and root of the potato, being 13 times more of soluble and nearly 7 times less of insoluble matter in the root. About 100 lbs. ashes are contained in 1981 lbs. of the pea stalk.

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ASHES.

	Per cent. Ashes.	In 100 Ashes or in lb.		The Soluble contained							The Insoluble contained							
				Carbonate of Potassa.	Carbonate of Soda.	Sulphate of Potassa.	Sulphate of Soda.	Chloride of Sodium.	Silicate of Potassa.	Carbonate of Lime.	Magnesia.	Phosphates			Silica.	Total.		
1. Beech-wood.....	0.384	27.77	72.23	11.72	13.37	3.49	—	trace	—	49.54	7.74	3.32	2.92	0.76	1.51	1.59	2.46	97.42
2. Beech-bark.....	6.618	3.02	96.98	3.02	—	—	—	—	—	64.76	16.90	2.71	0.66	0.46	0.84	—	9.04	98.39
3. Beech-wood.....	5 1300 lb.	1.388	3.612	0.566	0.618	0.124	—	—	—	2.477	0.687	0.166	0.146	0.046	0.075	0.079	0.123	
4. Beech-bark.....		0.94	2.833	91.162	2.833	—	—	—	—	60.883	15.986	2.547	0.620	0.043	0.078	—	8.497	
5. Fir-wood.....		2.95	97.0	11.30	7.42	trace	—	trace	—	50.94	5.60	3.43	2.90	1.04	1.75	trace	13.37	97.74
6. Fir-bark.....		2.95	97.05	2.95	—	—	—	—	—	64.98	0.93	5.03	4.18	1.04	2.42	—	17.28	98.81
7. Fir-leaves.....		29.09	70.91	—	2.95	2.76	—	—	—	15.41	3.89	38.36	—	—	—	—	12.36	70.02
8. Fir-wood.....	5	0.936	4.064	0.565	0.371	—	—	—	—	2.547	0.280	0.171	0.145	0.052	0.087	—	0.668	
9. Fir-bark.....	1500 lb.	27	0.801	26.199	0.801	—	—	—	—	17.544	0.251	1.358	1.128	0.281	0.653	—	4.665	
10. Fir-leaves.....		25.23	7.65	17.58	—	—	0.67	—	—	3.888	0.90	9.678	—	—	—	—	—	3.118
11. Leaves of a young Pine		12.70	86.30	10.72	1.95	—	—	3.90	63.32	1.86	6.35	0.88	0.71	—	—	—	10.31	100.
12. Havana Tobacco.....		24.15	75.85	6.18	1.94	—	7.39	8.64	—	51.38	7.09	9.04	—	—	—	—	8.26	99.92
13. Hanoverian Tobacco.		23.07	76.93	—	1.61	11.11	1.09	9.24	—	40.00	4.27	17.95	—	—	—	—	15.25	100.52
14. Stalk of Field-bean...		32.91	67.09	13.32	16.06	3.24	—	0.28	—	39.50	1.92	6.43	6.66	3.49	—	—	7.97	98.87
15. Stalk of Pea.....		27.82	72.18	4.16	8.27	10.75	—	4.63	—	47.81	4.05	5.15	4.37	0.90	1.20	—	7.81	99.10
16. Stalk of Pea.....	5.047	20.05	79.95	4.34	11.99	—	—	3.72	—	49.73	1.38	1.15	7.82	3.64	—	—	15.54	99.31
17. Potato-plant.....		6.97	93.03	—	4.69	—	—	2.28	—	—	3.76	5.73	—	1.30	2.75	—	29.81	100.00
18. Potato-tuber.....		85.81	14.19	—	—	—	—	—	—	—	—	—	—	—	—	—	—	100.00

ASPARAGIN.

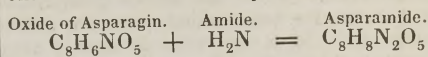
It is often asked, whether plants will contain the organic constituents found in their ashes, even when they are not offered to them in the soil, and whether these elements are necessary for their development. This has been partially answered by some excellent experiments lately made by Wiegmann and Polstorff. They employed two soils, one which consisted of pure quartz sand, ignited, digested in aqua regia for 16 hours, washed and dried; the other the same sand with an admixture of various salts of alkali, earth, and oxide of iron. In these were sowed common vetch (*Vicia sativa*), barley, oats, buckwheat, and clover; they were watered by pure distilled water and protected from foreign influences. Those in the 1st grew feebly, some flowered, others did not, and none bore fruit; in the 2d they grew luxuriantly, flowered and fruited. The same quantity of seed as was sown was incinerated and the ashes analyzed; the cleaned plants were also incinerated and their ashes analyzed. The ashes in the plants grown in the pure sand was double that in their seed; of those grown in the 2d soil 4 to 5 times as much as in their seed. The organic matter of the plants in the 2d was $2\frac{1}{2}$ times as much as that in the 1st. The sand was then subjected to analysis and found to contain about 2 per cent. of potassa, lime, alumina, and oxide of iron. The sand was then mixed with water, carbonic acid passed through it for a month, the water evaporated and analyzed; it contained silica in addition to all the bases just mentioned. The particles of felspar, &c., are therefore decomposed slowly by carbonic acid and furnish alkali, &c., to plants. Seed of cress were also sown in fine clippings of platinum wire, and watered with distilled water. They grew luxuriantly, but their ashes were found to weigh only the same as the ashes of the seed employed. It hence appears that inorganic elements are necessary to organization, and that when destitute of them they droop and languish. It is, however, probable that all the substances found in ashes are not essential, but that potassa and soda, lime and magnesia, oxide of iron and alumina may replace each other as they do in the mineral kingdom. (Prize Essay read in Göttingen, 1842, from *Berz. Arsberütelse*, 1843.)

ASPARAGIN. *Chem. Syn.* Asparamide, Althein, Agedoile. A peculiar principle found in the root of the Althea, in asparagus, in liquorice root, &c. It is prepared from althea-root; 1. by macerating it with milk of lime, filtering, precipitating with carbonate of ammonia and evaporating to the consistence of syrup; 2. by extracting with lukewarm water, concentrating by evaporation, filtering, and placing the liquid in a cool place for several days; this method yields 2 per cent. of asparagin from the root (*Henry and Plisson*); 3. express the juice of asparagus, clarify and evaporate, as in 2. (*Robiquet*.)

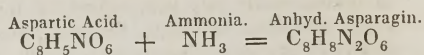
Prop. Right rhombic octahedra, rhombic or six-sided prisms, transparent, of a cooling, somewhat nauseous taste; $G. = 1.519$ at 57° ; soluble in 58 pts. water at 55.4° , much more soluble in hot water; more soluble in dilute alcohol, not soluble in absolute alcohol or

ASPARAGUS-STONE.

ether. It yields ammoniacal products by distillation. Heated with acids or alkalis it is resolved into ammonia and aspartic acid. According to the analysis of Liebig its formula is $C_8H_8N_2O_6 + 2HO$, (or $C_8H_4NO_3 + HO$). When dried at 248° it falls to a fine powder, losing 12-133 per cent. water ($2HO$), so that the formula of anhydrous asparagin is $C_8H_8N_2O_6$. Pelouze and Boutron give the formula $C_8H_8N_2O_5$, and regard it as an amide of a lower oxide of the radical in aspartic acid.



By adding one eq. water it forms aspartic acid and ammonia, and by another eq. water, aspartate of oxide of ammonium. According to Liebig, the decomposition of asparagin is represented thus:



By adding 1 eq. water it forms aspartate of oxide of ammonium, by 2 eq. the same salt crystallized, which is metameric with hydrated asparagin.

Aspartic acid. *Prep.* by boiling asparagin with baryta, litharge, or potassa, precipitating the 1st by dilute sulphuric acid, the 2d by sulphuretted hydrogen, and neutralizing the 3d by chlorohydric acid; it crystallizes from a hot aqueous or cold dilute alcoholic solution. Fine pearly scales or leaves, inodorous, feeble taste, similar to asparagin, soluble in 128 pts. water at 15.3° , much more soluble in hot water, more in muriatic acid, less in dilute alcohol, insoluble in absolute alcohol; the aqueous solution reddens litmus; nitric acid may be distilled over aspartic acid without change. According to Liebig, the formula of the crystallized acid is $C_8H_5NO_6 + 2HO$, and that of the dry $C_8H_5NO_6$. —Pelouze and Boutron give the formula $C_8H_7NO_7$ for the crystallized and $C_8H_6NO_6$ for the dry acid. When boiled with strong potassa, it is resolved into ammonia and a new acid, which has not been examined.

Salts. Admitting it to be a bibasic acid, the general formula of its neutral salts is $C_8H_5NO_6 + 2MO$ and of its basic the same, with one MO . It may be that the latter are the neutral and the former the acid salts. *Aspartate of potassa* is deliquescent, uncrystallizable, of soda crystallizable; of ammonia difficult to crystallize, becoming acid by evaporation; of baryta small white opaque crystals; of lime, a gummy mass, the basic salt is crystallizable, reacts alkaline, precipitates oxides of lead and silver and sesquioxide of iron; of magnesia, both neutral and basic, is gummy; of zinc granular, crystalline; of nickel green, amorphous; of copper small blue needles with silky lustre, little soluble in pure water, soluble by aid of heat in the soda-salt, but separating by evaporation; the precipitates, with basic acetate of lead and salts of black oxide of mercury and oxide of silver, are soluble in nitric acid and in an excess of the metallic solution. A. of quinine, very soluble, drying to a dendritic, silvery mass; of cinchonin, long prisms; of morphin, a gummy mass, exhibiting a tendency to crystallize. (*Berz.* vii. 313; *L. P. W., &c., Wörterb.*)

ASPARAGUS-STONE. See **APATITE**.

ASPARAMIDE, ASPARTIC ACID. See ASPARAGIN.

ASPHALT. *Tech. Ger.* Erdpech, Judenpech. A native resinous substance found in some quantity on the shores of the Dead Sea, on the island of Trinidad, &c., and supposed to be raised by springs from decomposing coal-formations. Black, shining, fuses at about 212° , burns readily with a white flame and much smoke, leaving little ashes; by dry distillation it yields empyr. oil, a little ammoniacal water, combustible gases, and leaves $\frac{1}{3}$ carbon, containing in its ashes silica, alumina, oxide of iron, &c. It is insoluble in water; alcohol extracts 5 per cent. of a yellow resin; ether extracts from the residue 70 per cent. more of a black or brownish black resin; the portion insoluble in alcohol and ether is readily soluble in oil of turpentine and naphtha, with difficulty in lavender-oil; this last, called by Boussingault *asphalten*, is black, shining, softens at 572° , and has the composition $C_{20}H_{16}O_3$. (*Boussing.*) The relative quantities of these substances vary, for B. found the asphalt from Coxitamba, S. A., to consist chiefly of asphalten, which was of more difficult solubility than usual. Sulphuric and nitric acids convert a part of asphalt into artificial tannin; potassa dissolves a large portion of asphalt with a black color. See PETROLEUM.

ASPIRATOR. *Chem.* An apparatus contrived by Brunner, for producing a current of air, which is represented in Pl. V. fig. 8. A and B are two cylinders of sheet-tin, each of about a cubic foot content. A metallic rod *a b* unites them, through the middle of which another *a c*, serving as an axis of revolution, and supported by the wooden uprights *c f d e*. Two tubes, *gh*, *ik*, connect the cylinders, and are provided with cocks, one of which is an ordinary one, the other a two-way cock; by the former the cylinders are made to communicate; by the latter, either cylinder may at pleasure communicate with the air. On the bottom of each drum and near the edge is a tube K, the position of which must correspond on each but on opposite edges of the bottom, and it may be closed by a cork or connected with a tube. A glass tube, *m l*, connecting the bottom and top of one cylinder, and on the outside, indicates the height of water within. On the side of each cylinder is an eye by which it can be hooked fast to the wooden uprights. The instrument is thus employed: Both cocks and the lower tube being closed, the cylinder A is filled with water, and the upper tube K connected with the vessel or apparatus from or through which air is to be drawn; the ordinary cock is then turned so that the water may flow into the lower cylinder, and the other cock so that the air in the lower cylinder may pass into the external air. The water flowing into B, as indicated by *l m*, is replaced by air through K until A is emptied. The cylinders are then reversed after closing the cocks, the tube K closed by a cork, the apparatus connected with the opposite tube, and the cocks opened in a similar manner as before until B is emptied.

Modifications of Brunner's aspirator have been proposed by Abendroth (*Pogg. An.* liii.

617) and Bolley (*An. der Ch. und Phar.* xl. 322), in which the axis is a tube serving as a conduit for the air instead of the tubes K. In Bolley's there is but one wooden upright with the axis, on which the cylinders revolve, and in the direction of the axis is a tube in which tubes meet, one from either cylinder. The apparatus from which air is to be drawn being connected with this tube which is stationary, the difficulty of adjustment is obviated. The aspirator may evidently be modified so that air or a gas may be either drawn or forced through an apparatus or vessel.

The apparatus on Pl. II. fig. 1, may serve the purposes of an aspirator, although far less convenient. See ORGANIC ANALYSIS.

The aspirator is employed for drying a substance in hot air, for evaporation, sublimation, for analyzing mixed gases, &c., and with modifications might serve as a gas reservoir, &c. Berzelius remarks that it is one of the most useful instruments to the chemist, and that it should find a place in every laboratory.

ASSAY. *Mining. Coinage.* In general an assay is the analysis of an ore or artificial substance, whether quantitative or qualitative, with a view to determine the valuable metallic constituents alone, and is chiefly applied to the precious metals, to copper, lead, tin, antimony, bismuth, and a few others. In a more limited sense, it is applied to the determination of gold, silver, platinum and palladium, qualitatively and quantitatively, whether they are in the ore or alloyed artificially. Assaying therefore is one kind of analysis. For the former more general view, refer to the article ANALYSIS, and the several metals which may become the objects of an assay. In its most limited sense, it designates the processes employed in coinage, for determining the quantity of gold or silver in alloys of those metals, and divides itself into the *humid* and *dry* assay.

Dry assay. It depends on the same principles as cupellation, viz. that oxide of lead carries the oxides of other metals into the porous cupel, leaving the precious metal on the surface. The weighed metallic alloy, consisting usually of the precious metal with copper, is rolled in a small sheet of pure lead, so much lead being added as is supposed to be sufficient to oxidize and remove the copper, &c.; and is then placed in a muffle brought to a cherry-red heat, where the whole soon fuses from the increased fusibility of the alloy with lead. The air having access, the lead oxidizes, and a portion passes off in vapor; by its ready oxidation it induces the more ready oxidation of the associated metals, whose oxides enter into fusion with the fusible oxide of lead, and are thus absorbed together by the porous cupel. As the last portions of lead leave the silver, the peculiar brightening and immediate solidification of the latter metal are observed, as in ordinary cupellation.

Humid assay. This method of assay for silver was carried into successful operation by Gay-Lussac, and has the advantages of being more exact, and more easily executed than the dry assay, but requires more time. It depends on the principle that a solution of silver is completely precipitated as chloride of silver by

ASTRINGENTS.

a solution of common salt (chloride of sodium), and perfectly accurate results are attainable by it except when mercury and lead are present; but even in the latter case, the difficulty of the precipitation of chloride of lead may be avoided, from its known solubility at an increased temperature. A certain quantity of the silver alloy is dissolved in pure nitric acid, and a given measured quantity of a standard solution of chloride of sodium is added, and the stoppered vial containing the solution placed in the agitator for a minute or more, when the chloride settles and the liquid is clear. Another solution is prepared by mixing 100 grammes of the normal solution of salt, with 900 grms. of water, so that if 100 grms. of the normal solution represented 1000 milliemes of pure silver, one gramme of this decuple solution will represent 1 millieme of pure silver. The decuple solution is now added gramme-wise, and agitated to settle the chloride of silver, so that the effect of the succeeding gramme may be observed, when it is again tested. By a careful attention to the temperature of the standard solution, and ascertaining from time to time its state by testing with a solution of pure silver, and by care and experience in the various parts of the process, an extraordinary degree of accuracy is attainable, and even a degree of rapidity falling but little short of the dry assay.

Assaying Gold. This is a mixed dry and humid assay, and we may suppose an alloy to contain gold, silver, and copper. The first test frequently employed as approximative, is to try the streak of the alloy on touch-stone, (a hard and compact Hornstone, Basanite, &c.,) compared with the streak of needles, the composition of which is known; the needles may be pure gold, or alloyed with silver, or with copper, or with both silver and copper in due proportions. This being ascertained, it is then cupelled with lead to exclude copper, &c., a certain and fixed quantity of pure silver being added according to the quantity of gold supposed to be present. Chaudet employs 500 milliemes of the fine gold for assay, cupels it with 1500 m. silver and 1000 lead; the button is then rolled out into a strip several inches long, and into the spiral cornet, which is boiled in a matrass for 3 to 4 minutes, with nitric acid of 22° B.; this acid being poured off, it is boiled for 10 minutes with acid of 32° B., and again, for 8—10 minutes with acid of 32°. The cornet is washed, heated in a little porous crucible to render it more solid, and weighed. By adding silver, the whole of this metal may be extracted from the gold, but attention to the strength of acid, and the time of boiling is

ATACAMITE.

requisite to avoid the extraction of gold at the same time. See ANALYSIS, CUPELLATION, GOLD, PARTING, SILVER. Consult the excellent work of Chaudet, "*L'art de l'essayeur*," for minute and valuable details on the process of assaying.

ASTRINGENTS. *Med.* Medicines which produce contraction of the living tissues. Their general effects are manifested by greater firmness of the muscular fibres, greater rigidity of the blood-vessels and diminution of their caliber, and contraction of the exhaling secreting orifices, whereby they check hemorrhage, and diminish exhalation and secretion. In the mouth, they produce a styptic or astringent taste. In moderate doses, they are capable of producing the same constitutional effects as tonics (*Pereira*), but they are principally employed for their local effects, to obviate relaxation of the fibres and tissues, and to prevent and check excessive discharges.

Astringents may be divided into two sections, the vegetable and mineral. The vegetable astringents owe their peculiar properties to the presence of tannin or tannil, which is found in all of them. (*Wood*.) They differ only in the proportion of the latter principle, and in the other ingredients with which it is associated. The mineral astringents have nothing in common, but their property of astringency. To the former belong: oak bark, galls, kino, catechu, logwood, rhatany, geranium, tormentil, bistort, pomegranate-rind. To the latter, alum, the preparations of lead, zinc, and iron, and sulphuric acid.

ATACAMITE. *Min.* Syn. Prismatoidal Habroneme Malachite, *Mohs*; Salzkupfererz, *Wern.*; Hydrous oxy-chloride of copper.

Descrip. Crystals minute, Right Rhombic, the planes of vertical prism M on M = 97° 20'; the prevailing forms are horizontal prisms of 1st and 2d order, constituting a rectangular octahedron, with terminal planes of axes, octahedral planes, and vert. prism. Cleaves perfectly and brilliantly parallel to term. plane of main axis, imperfectly parallel to vert. prism. H. = 2.5—3.5. Gr. = 4—4.3. Color various shades of green, with apple-green streak; lustre vitreous, adamantine; subtransparent, subtranslucent; brittle.

Behavior. Colors the blowpipe flame bluish green, fusing and reducing to a globule of copper; in a closed tube, gives off acid water; at a higher heat sublimes green chloride of copper; very soluble in acids, giving a rich blue color with ammonia.

Analysis of massive, 1. by Klaproth, 2 by Proust; 3 of granular, by Proust; 4 of crystallized by J. Davy; 5 of A. from Cobija, by Berthier.

	1.	2.	3.	4.	5.
Oxide of copper.....	72.0	76.5	70.5	73.0	50.00
Chlorohydric acid.....	16.3	10.5	11.5	16.2	Copper 13.33
Water.....	11.7	12.5	18.0	10.8	Chlorine 14.92
	—	—	—	—	Water 21.75
	100	99.5	100	100	100

According to 5 its formula is $\text{CuCl} + 3\text{CuO} + 6\text{HO}$; according to 1 and 4 $\text{CuCl} + 3\text{CuG} + 3\text{HO}$.

Locality. Atacama and Taracapa in Peru and Chili; iron mines of Schwartzenberg Saxony; lavas of Vesuvius formed by the ac-

ATMOSPHERE.

tion of muriatic vapors on carbonates of copper.

ATMOSPHERE. *Ger.* Dunstkreis. The immense mass of elastic fluid which surrounds the globe which we inhabit is called its atmosphere (from *ατμός*, vapor, and *σφαῖρα*, a sphere), and the mixture of gases of which it consists, *atmospheric air*, or simply *the air*.

Nothing perhaps can be more interesting than a knowledge of the nature of this fluid in which we live and move. So intimately connected, indeed, is our whole existence and that of all other living beings with the atmosphere, that those planetary bodies in which no atmosphere has been discovered are generally considered in consequence thereof destitute of organic beings. As our life depends for its existence and continuance on it, so our health and comfort is intimately connected with the changes which it undergoes, and cannot therefore be attended to without a thorough knowledge of its physical and chemical nature. If it be furthermore remembered that it is the principal agent in combustion, and that, until the discovery of the steam-engine, it constituted an important mechanical power on which, until lately, navigation has from time immemorial been dependent, and that possibly the time is not far distant when it may become the principal medium for locomotion, its importance in the condition and development of mankind will easily be conceived.

Chemical nature of the atmosphere. Common atmospheric air was for a long time considered as an element, until Scheele and Lavoisier succeeded in demonstrating its compound nature. Lavoisier's experiment is very instructive. He boiled mercury in a matrass filled with atmospheric air, and communicating with a graduated bellglass, also containing atmospheric air over mercury. The mercury in the matrass was kept boiling for twelve days, till no further diminution of the air in the bellglass was perceptible. By this process the mercury was partly converted into a red powder (oxide of mercury), while the remaining air (nitrogen) was found unfit for respiration or combustion. Animals introduced into it died in a few moments, and a candle was extinguished instantaneously, as if immersed in water. On the other hand, by heating the red powder into which the mercury was converted, by absorbing a portion of the air, it separated again into metallic mercury and a colorless gas (oxygen), in which animals were capable of living longer than in an equal volume of common air, and in which a glowing taper would again become inflamed and burn with increased brilliancy. Atmospheric air was thus proved to consist of at least two gases of different and almost opposite natures.

Besides these two gases, oxygen and nitrogen, which form its main ingredients, the atmosphere contains also a small portion of carbonic acid, and variable quantities of vapor of water. The two latter, although in less quantity, form a no less important part in the economy of animals and plants than the oxygen; while the nitrogen, as far as yet ascertained, seems mostly to serve for the purpose of a neutral diluent for the other ingredients.

ATMOSPHERE.

The following may be considered as the average constitution of the atmosphere:

	By volume.	By weight.
Oxygen.....	20.55	22.76
Nitrogen.....	78.16	76.15
Vapor of water.....	1.25	1.03
Carbonic acid.....	0.04	0.06
	100.00	100.00

To the above constant ingredients of the air may also be connected several accidental substances, dissolved or diffused through it from local or special causes, becoming in some instances the source of great distress or annoyance to man.

Oxygen. It has been found by carefully conducted experiments that the proportion of oxygen in 100 volumes of dry air is not subject to variation, but remains constant, amounting to between 20.8 and 21 volumes. This result has been obtained with air taken in cities as well as in the country, from under the equator or from the arctic regions, from the tops of high mountains or in valleys, from great elevations in the air or from the level of the sea, in day-time or during the night. Even in marshes, or when taken from crowded rooms, theatres, &c., it exhibited no perceptible deficiency of oxygen. The proportion of oxygen and nitrogen may therefore be considered as constant, or at least not to vary more than between one and two-tenths of one per cent., which may be considered within the limits of experimental accuracy. Generally, omitting carbonic acid and water, it is considered as containing 21 volumes of oxygen and 79 volumes of nitrogen, or by weight 23.1 oxygen and 76.9 nitrogen. The last results of Dumas and Boussingault yielded oxygen 20.81, nitrogen 79.19, or by weight, oxygen 23.01, nitrogen 76.99, with a variation in the results of 0.17 per cent. It may, however, be remarked that, according to some very lately published results by Lewy of analyses of air from the North Sea and from the isle of Guadeloupe, he has arrived at the conclusion that the quantity of oxygen in the atmosphere varies, and that this variation, although within so small limits on the continent as to render its estimation somewhat uncertain, is nevertheless much greater over the sea, amounting to 0.46 per cent. His analyses were performed by the same method as employed by Dumas and Boussingault. See farther below.

If the air were of uniform density, its height, as inferred from the barometer, would be about 5.238 miles. Making an allowance for the contained vapor of water and carbonic acid, and assuming its height to be 4.6 miles and the radius of the earth to be 3956 miles, the volume of the atmosphere would be 906 millions of cubic miles, of which the oxygen would form 19,025,000 cubic miles.

The quantity of oxygen consumed by a grown person in 24 hours is, according to Lavoisier and Davy, about 45,000 Par. cub. inches, or 26.04 cubic feet. From this it has been calculated that the yearly consumption of oxygen by all mankind, assumed at 1000 millions of people, would only amount to about 77.6

cubic miles, and that therefore the present amount, if it could be consumed to the last portion, would suffice for 2,451,000 years, and if the same number of people had existed since the time of the creation, only $\frac{1}{453}$ of the present volume of oxygen would have been consumed, a diminution entirely too small to be ascertained at present by experiment. One-tenth of a per cent. of the air contains oxygen enough for the supply of the whole present population for 10,000 years.

If thus on the one hand it must be admitted that the quantity of oxygen consumed by mankind, even for a considerable length of time, could not diminish it sensibly; it must on the other hand be remembered, that much larger quantities are annually consumed by the whole animal kingdom, and by combustion and other oxidizing processes, and that a sensible diminution of the oxygen might at last occur, if this consumption were not in some other way counteracted. This is done by plants, which inhale carbonic acid and liberate oxygen. How far they in this point counterbalance the consumption, we have as yet no means of determining with accuracy. It will, however, afterwards be seen that even this is probably not the case.

The constancy of the proportion of oxygen in the composition of the air must be explained by the great mobility of its particles and the diffusive power of its constituents, by which any difference is rapidly equalized. The same must be supposed to take place in crowded places or rooms where the windows and doors are never so close as not to allow a considerable exchange of air to take place through them. For in hermetically closed rooms oxygen is known to disappear by respiration, and to be replaced by nearly an equal volume of carbonic acid. The oppression and other injurious effects of such air must therefore be ascribed more to the temperature and to the presence of other noxious substances, as carbonic acid and exhaled animal substances, than to a want of oxygen.

It has already been stated that, in abstracting the oxygen from the atmosphere by any substance which will combine with it, the remaining gas consists almost entirely of nitrogen (but mixed with a minute quantity of carbonic acid and watery vapor).

Nitrogen. The principal characteristic of nitrogen is its indifference to oxygen, as well as to other substances, and its consequent apparent reluctance to enter directly into combination with them. Its use seems, therefore, principally to be to dilute the oxygen; for, from the powerful affinity of this latter substance, it is obvious, that if it alone constituted our air, it would soon, with the present arrangement of our earth and its inhabitants, produce universal destruction, for all animals would perish from the excessive influence of the oxygen on the blood and the respiratory organs, and the greatest part of all combustible matters would soon be involved in one general conflagration. It may, however, be remarked that, although the nitrogen of the air does not seem necessary by itself to the continuance of life, nor any direct reaction between it and the living crea-

tion has yet been found to exist, yet it forms an invariable and essential constituent of both animals and plants.

From the fact of the invariable proportion of the oxygen to the nitrogen, and this ratio being very nearly as 1 to 4, some chemists have advanced the idea that the air is a chemical compound of 1 volume of oxygen with 4 volumes of nitrogen, forming a compound with half as much oxygen as in nitrous oxide; but, if this were the case, it would afford the only instance of a mechanical mixture having exactly the same properties as a chemical compound. For an artificial mixture of oxygen and nitrogen in the same proportion does not differ in any respect from the air, and yet that they enter into no chemical combination by their mixture is evident from the absence of any change in temperature or volume. Besides the fact that nitric oxide abstracts oxygen from the air, being thereby converted into hyponitrous acid, would thus afford an instance of one oxide reducing another of the same radical and liberating the latter, which would be both improbable and without a parallel. The objection that the oxygen, as the heavier gas, ought in still weather to settle down at the bottom in the lower strata is unfounded, since gases mix together as liquids of different specific gravity, without any tendency to subsequent separation by mere gravitation. On the contrary, the law of diffusion of gases would make them mix and penetrate each other perfectly without any mechanical agitation.

Carbonic acid. The existence of carbonic acid in the air may be easily proved by exposing lime or barytic water in an open vessel to the air, or passing the latter through their solution, when a precipitate will be formed, which effervesces by the addition of an acid, and consists of carbonate of lime or baryta. Like the two former cases, the carbonic acid is diffused through the whole atmosphere; its proportion is, however, very small. By a series of experiments, carefully performed by Th. de Saussure, it has been ascertained that the mean proportion of carbonic acid in the air does not amount to more than 0.0004, or 4 volumes in 10,000 volumes of air, but that this amount varies from 0.00057 as a maximum to 0.00032 as a minimum. During the night its proportion is greater than during the day, and in populous cities greater than in the country, and also in winter and in high situations greater than in summer, or in low situations, owing probably to the effect of vegetation. Dry weather and frost seem also to increase its amount, probably by preventing absorption by the soil, while over lakes and other waters, and after rain, it is somewhat less.

Notwithstanding the small proportion which the carbonic acid bears to the whole atmosphere, its presence is of the highest importance in an economical point of view. We have seen that the animal kingdom consumes annually an immense quantity of oxygen which it converts into carbonic acid, while, on the other hand, the plants again absorb the carbonic acid and return the liberated oxygen to the air; for, although during the night they absorb

oxygen and exhale carbonic acid, the reversed action during the day predominates greatly. The very existence and continual growth of plants seem, therefore, to depend on the presence of the carbonic acid. How far animals and plants counterbalance each other we have not yet been able to ascertain by direct experiments, but considering the continual increase of carbonaceous matter in the soil, and the immense deposits of carbon as coal and lignite, which owe their origin to a previous vegetation, it would seem, indeed, that the amount of carbonic acid in the atmosphere must have been formerly greater, and that its absorption by plants so far prevails over the causes which reproduce it as to cause its slow but steady diminution.

Carbonic acid acts as a poison to man when inhaled. Its accumulation, by respiration, and the burning of lights in crowded and lighted rooms, constitutes, therefore, a frequent cause of the vitiation of the air in such places, and its injurious effects are even felt before it reaches the amount of one per cent.

Vapor of Water. A continual evaporation taking place from seas, lakes, rivers, and other waters, as well as from the soil in general, these vapors diffuse themselves through the air, and form an important constituent of it. Vapor of water not being a permanent gas, as the other constituents of the air, but condensible again to water by cold; their presence can easily be proved by reducing artificially its temperature. Thus, if a pitcher be filled with ice, the vapors of the air will be seen to condense on its outer surface, as a dew, and collect into drops of water. It has been asserted that, by the above evaporation, the water dissolves in the air as a salt in a liquid. But it has been found that evaporation takes place equally well in vacuo, and that here at equal temperatures the same amount of vapor will form in a given space as if it were filled with air. If, therefore, no other atmosphere existed, the earth would still be surrounded by an atmosphere of watery vapor; the quantity of it, therefore, only depends on the temperature. The atmosphere, therefore, so far from facilitating the evaporation of water, is rather an obstacle to its diffusion, since, in a vacuum, it would expand itself with the utmost velocity. That wind and other commotions of the air facilitate the evaporation, depends upon the removal of the vapor formed from the surface of the water, whereby further evaporation would be prevented.

The amount of vapor varies according to the temperature of the atmosphere and other circumstances, from $\frac{1}{2}$ per cent. to more than 4 per cent. by vol. Verner found as a mean of 50 experiments, in 1000 parts of air, 8.47 pts. of vapor, the maximum being 10.18, the minimum 6.1. In the forenoon, and before 2 o'clock, the mean was 7.97, after 2 o'clock till evening, 8.85. In general, the higher the temperature, the greater is the absolute quantity of vapor. In the same way it is greater in summer than in winter, in day-time than in the night, in warm and low countries than in cold and mountainous, and in the proximity of seas and

rivers, greater than farther inland. Much depends also on local circumstances, as the peculiar property of the soil, the facility of drainage, the prevalence of certain winds. The atmosphere, however, rarely contains at any temperature the full amount of vapor which it is capable of taking up. If this be the case, all further evaporation from the surface of the earth into it must of course cease, while, on the other hand, if its content of vapor be considerably below its capacity for it, evaporation is much more rapid, and the air is then said to be dry. Hence the different influence between dry and damp air on the animal body, which must continually throw off a certain amount of moisture by evaporation from the skin, in order to keep it of a certain moisture and temperature, which is necessary to the preservation of health.

If we compare the *absolute* quantity of vapor with the quantity which the atmosphere at the same temperature is capable of taking up, we obtain the *relative* quantity of the vapor or the degree of moisture. It will thus be seen, that with the same absolute quantity of vapor, the moisture of the air depends on the temperature, and that at a higher temperature, the air may still be drier than at a lower temperature, although the absolute quantity of vapor be larger in the former than in the latter case, and that air which at a certain temperature feels damp and uncomfortable, by a slight increase in the temperature may become comfortable. In summer, and in warmer climates, the absolute quantity of vapor is generally larger, but the relative quantity smaller. The relative quantity of moisture in the atmosphere, may be determined by ascertaining how far the air may be cooled down before it deposits any moisture on a cooled body, which temperature is called its dewpoint. (See *HYGROMETRY*.) When the atmosphere becomes perfectly saturated with vapor, the slightest cooling will cause the vapor to condense and assume the liquid form. When this takes place, the condensed vapor separates first as fine vesicles floating about in the air of from $\frac{1}{28000}$ to $\frac{1}{4000}$ inch in diameter, thus constituting the common phenomena of clouds and fogs, which by collecting into drops or freezing, form rain or snow. For the explanation of these and other phenomena, we refer to treatises on meteorology.

The moisture of the air plays an important part in the economy of the earth. To it is due the constant irrigation of its surface, keeping up a constant circulation by evaporating from the sea and other great reservoirs, being carried inland by the wind and other commotions of the air, and there again condensing on mountains and other high and colder places, collecting into springs, creeks, &c., or depositing itself more diffusely as dew, or precipitating itself more vigorously as rain, &c., and thus again returning to its first origin. Without the presence of the moisture in the atmosphere, neither plants nor animals could live. To it is also due the constant decomposition and decay of animal and vegetable substances; and even the rocks and mountains

wear away and decay under its all leveling influence, for besides its own dissolving power, it seems to be that which lends to the other destroying agencies of the atmosphere their force and efficacy, for without it they seem inert, at least at ordinary temperatures. In dry air, steel does not rust, nor does wood decay.

Other ingredients in the Atmosphere. Besides the above-named constant ingredients of the atmosphere, a number of other gases and vapors are known to enter it in certain localities, but they are too inconsiderable in quantity to be detected afterwards in its general composition. As such may be mentioned sulphuretted hydrogen, chlorohydric acid gas, carburetted hydrogen, &c. Boussingault has proved the constant presence of a minute trace of a carburetted hydrogen, or some other similar compound, by passing atmospheric air over ignited oxide of copper, whereby he obtained carbonic acid gas and water, from which he had carefully freed it previously. The air had also previously passed through concentrated sulphuric acid, so that they could not derive from dust or other mechanically suspended organic particles. The final products of the decay of animal and vegetable matters being carbonic acid, water, and ammonia, which escape into the atmosphere, Liebig infers that the latter gas ought never to be absent, although in too minute quantity to be detected directly by ordinary experiment, but according to him, it always exists in rain water. Rain is also the principal mean of carrying down again most other accidental substances, either dissolved or suspended in the atmosphere, among which may be included the different miasmata and matter of contagion (see these), which are perceptible only by the senses or by their effect upon the human system, but cannot otherwise be detected by chemical tests, although we may destroy them, or at least their injurious effects by chemical means, such as by muriatic, nitric, or acetic acids, or chlorine gas. The action of the atmosphere itself tends necessarily to destroy or oxidize them by the combined influence of oxygen with light and heat.

Physical properties of the Atmosphere. We have thus seen that the atmosphere consists of a mechanical mixture of three permanent gases, and one condensable. Its physical and mechanical properties are therefore such as might be calculated from a mixture of them. 100 cubic inches of atmospheric air, deprived of its carbonic acid and aqueous vapor, weighs according to Dr. Prout, 31.0117 grains, at 60° temperature, and 30 inches barometric pressure, and its specific gravity at this temperature is generally taken as the standard for comparison with other gases, and therefore set equal to 1 or 1000. Compared with water at 62° it is 815 times lighter than water, and 11,065 times lighter than mercury. At 32° Fahr. it is 770 times lighter than water or its spec. grav. = 0.001299 that of water at 39° = 1. The weight of the atmosphere pressing upon the surface of the earth, is equivalent to about fifteen pounds on each square inch of surface, or

equal to the weight of a column of mercury of 30 inches, or a column of water of nearly 34 feet in height. But this pressure varies continually from the different changes in its variable constituents, from its commotion by currents of air, and from other causes. These differences are indicated by the rise or fall of the mercurial column in the barometer, (see this). Its mean pressure being taken at thirty inches of mercury, the contribution to this pressure of its different constituents, which may be considered as independent atmospheres, will be as follows, the amount of vapor being calculated from the capacity of the air at 50°.

Pressure of the Oxygen.....	6.828 inches.
“ Nitrogen.....	22.845
“ Watery vapor..	0.309
“ Carbonic acid..	0.018
	30.000

As the different strata of the air are subjected to the pressure only of the superincumbent strata, it follows, that the pressure must decrease from below upward, and as the elasticity of the air will cause it to expand, as the pressure is removed, its density will also decrease; but as we ascend in a regular arithmetic progression, the density of the air decreases in a geometrical progression. The decrease in density is therefore much more rapid than the increase in height. So that for every 2.705 miles (11,556 feet), the density is about halved, as shown by the following table.

Height above the sea in miles.	Density.
0.....	1
2.705.....	$\frac{1}{2}$
5.41.....	$\frac{1}{4}$
8.115.....	$\frac{1}{8}$
10.82.....	$\frac{1}{16}$
13.525.....	$\frac{1}{32}$
16.23.....	$\frac{1}{64}$

It might be supposed from this, that the atmosphere would extend itself infinitely into space: but that it does not extend to several of the other planets, can be proved by astronomical observations. It certainly has a limit, either from a limit in the elasticity or expansibility of gases, or from the counteraction of these properties by the cold prevailing in the higher regions. From calculations founded on the phenomena of refraction, the sensible atmosphere would seem not to extend beyond 45 miles.

The absolute refractive power of the atmosphere is 0.0005891712, and its relative power considered as unity. Its specific heat is also assumed as unity for comparison with other gases. Compared with that of water it is = 0.2669. By rarefaction its capacity for heat is increased, but not in a direct ratio.

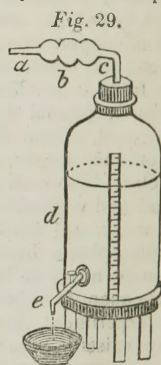
Like other gases, atmospheric air expands 0.002028, or $\frac{1}{493}$ of its bulk at 32°, for each degree of Fahrenheit. If, therefore, the air at any given place become heated, it expands, whereby it becomes lighter than the rest, and ascends, being replaced by colder and heavier

air flowing into its place from the sides, which again, in its turn, becoming heated, ascends in the same manner, and thus constitutes an ascending current or upward draft from the place where it is heated. Were it not for this no fire could continue for any length of time, since it must necessarily be extinguished as soon as the surrounding oxygen were absorbed, but the air being heated, at the same time it becomes lighter, and ascends, and thus causes an afflux of fresh air from the sides or from below, by which the combustion is maintained. The different commotions of the air, such as wind, gales, and hurricanes, owe their origin also to the same cause, the primary movement being always an ascending current, produced by the heated and expanded air, over some spot rising in a vertical column, and the denser and colder air rushing towards this point, and thus producing the above horizontal currents on the surface of the earth.

The temperature of the atmosphere is greatest near the earth, because the air transmits the rays of light without decomposing them, and cannot, therefore, be heated by them before they reach the surface of the earth, where they are decomposed and their heat set free. The air, which thereby becomes warmed, ascends and mixes with the upper colder strata. This is the reason why the atmosphere becomes colder as we ascend into it, until, even in the hottest summer season, its temperature sinks below the freezing point. In the lower strata this decrease of temperature has been found to amount to about 1 degree for every 352 feet of ascent, although at greater elevations the decrease is probably less rapid. This is also the reason why the temperature decreases in ascending high mountains until, even in the warmest climates, the region of perpetual congelation may be attained. Thus the summit of the Andes under the equator are covered with perpetual snow and ice. The height at which this line of perpetual congelation is attained has been fixed at 15,207 feet under the equator, but decreases progressively in higher latitudes, being 3818 feet at 60° lat., and only 1016 at 75° lat.

The blue color of the sky is probably peculiar to it. Brewster has shown that it is due to light that has suffered polarization, being, therefore, reflected light. The atmosphere must therefore have a disposition to absorb the red and yellow rays, and to reflect the blue rays. If the air were a perfect conductor of light, the sky would appear black, and the light would be very unequally distributed on the surface of the earth, while now the solar rays are reflected from the atmosphere and diffused more uniformly through it. The color of the air is, however, only observable when viewed in a mass. At great heights the blue color appears darker, owing to the darkness of space beyond it. The gradual transition of the blue color into light blue, and white nearer the surface of the earth, is owing to reflected light from vesicular vapor suspended in the air. The red and golden tints of clouds seem to be owing to a peculiar property of vapor, when mixed with air and on the verge of condensation.

Analysis of the Atmosphere. Formerly, when the purity of the air was supposed to depend on its content of oxygen, the estimation of the latter was considered of great importance, and obtained for itself the name of *Eudiometry*; the instruments employed for this purpose were called eudiometers; for the description of which, refer to *EUDIOMETERS*. At present these instruments are little used, except for illustration, other more perfect methods of analysis having since then been invented. Of the latter, that of Brunner consists in drawing by an instrument, to which he has given the name of aspirator, a certain volume of air freed from its moisture and carbonic acid over finely divided phosphorus, which absorbs the oxygen, and by its increase in weight indicates the amount of oxygen. Fig. 29 represents his apparatus. *abc* is a tube, into the



is introduced a quantity of loose cotton, with bits of phosphorus, which then, by gentle warming, are allowed to melt and spread over the fibres of the cotton. By *a* the tube is drawn out into a small orifice and connected air-tight by *c* to the vessel *d* by means of a perforated cork. The vessel *d* is filled with mercury, which may be made to flow out very slowly by turning the cock *e*, thus forcing the air to enter at *a*. In order, first, to deprive the air of its moisture and carbonic acid, a small tube, containing fragments of fused caustic potassa, is attached to the tube *abc* at *a*. The air then enters the latter, and, passing over the phosphorus, is deprived of its oxygen, so that nothing but nitrogen enters the vessel *d*. The increase in weight of the tube, *abc*, before and after the experiment, indicates the amount of oxygen, while the mercury, which drains from the vessel *d*, may either be measured by the graduation on the vessel, or by being received into a graduated vessel, and gives the corresponding volume of nitrogen, from which its weight may be calculated.

The same apparatus may be used for the estimation of the carbonic acid. This latter gas being present only in a small quantity, it requires special care and larger quantities of air in order to determine its amount with accuracy. For this purpose the tube *abc* is substituted by another, the foremost part of which contains slacked lime, while the part nearest to the vessel, *d*, is filled with asbestos moistened with concentrated sulphuric acid. In order to deprive the air of its moisture, another tube containing fragments of chloride of calcium is connected with it by means of a caoutchouc tube. The air then enters the second tube, where it yields its carbonic acid to the lime, and deposits any moisture which it might have taken up from it in the sulphuric acid. The increase in weight, before and after the experiment, indicates, therefore, the amount of carbonic acid, while the volume of air is deter-

mined, as before, by the amount of mercury or water drained out of the vessel *d*. Most of the experiments of Saussure on the amount of carbonic acid in the atmosphere and its variation were, however, determined before this method had been proposed, by filling an exhausted glass balloon with dry air, shaking it in this with barytic water, and determining the quantity of carbonate of baryta thus formed.

The estimation of the contents of watery vapor, or moisture in the atmosphere, may also be ascertained by Brunner's method, using chloride of calcium for its absorption. The variations in the moisture of the atmosphere are of special interest in meteorology. For the principles and methods by which this is effected, we refer to *HYGROMETRY* and *Hygrometers*.

Of late Dumas and Boussingault have, in their analysis of the atmosphere, substituted weighing altogether for measuring. They employed an exhausted glass globe, by which the air is drawn through a series of tubes, in which it is successively deprived of watery vapor, carbonic acid, and oxygen, by passing through sulphuric acid, caustic potassa, and finally through a red-hot glass tube containing fine copper-turnings, which have been previously oxidized, and again reduced by a current of hydrogen. They thus effected a complete absorption of the oxygen, so that at last nothing but pure nitrogen arrives in the exhausted globe, in which the weight of the nitrogen is ascertained, adding the weight of that portion which remains in the copper tube, the latter being furnished for this purpose with stopcocks at both ends. The amount of oxygen absorbed is ascertained by weighing after complete exhaustion, both before and after the experiment. In the same way, the increase in weight of the other tubes containing the sulphuric acid and the caustic potassa, yield the amount of aqueous vapor and carbonic acid. For a drawing of his apparatus, see *Ann. de Ch. et de Phys.* 3d ser. vol. iii. Pl. II. The results of their experiments have already been mentioned under the composition of the atmosphere.

ATOM. *Chem.* (α , $\tau\epsilon\mu\omega$, *indivisible*). The term atom expresses theoretically the smallest particle of matter which is believed to be incapable of division into parts. A discussion has been carried on from ancient times (said to have originated 1100 B. C.) relative to the finite or infinite divisibility of matter, and although the development of the atomic theory was supposed to give the strongest evidence of its limited divisibility, yet it may be fairly doubted whether the question can be decided. The divisibility of matter apparent to the naked eye, and ascertained by calculation, is almost beyond conception. Thus 0.01 of a cubic line of silver, dissolved in nitric acid, will produce a distinct milkiness in 500 cubic inches of clear water containing a trace of common salt, so that a particle of silver must be much less than the billionth of a cubic line in size. It will give a more tangible idea of a billion to say that a man counting

seconds by a watch day and night would require 31,675 years. (*Kane*.) The apparent infinite divisibility of matter is more clearly shown in the minuteness of living organized beings, millions of which would be required to constitute a point visible to the naked eye; and yet they possess more or less complex systems, each part of which again is a portion of an organized structure, which may even consist of other complex parts. The mind is lost in attempting to conceive of a limit to divisibility as long as materiality enters into the idea. Again we may divide a line into two parts, one of these divisions into two others, and we can conceive it to be infinitely divisible, for there must always be a part remaining capable of division.

On the other hand, experiments of Wollaston, Faraday, &c., have been adduced in support of the limited divisibility of matter. It is found that our atmosphere has a limit of 45 miles above the earth's surface, from which Wollaston argued that if infinitely divisible, it should extend through space by infinite repulsive force and be condensed around the larger planets, such as Jupiter and the sun, forming large and dense atmospheres, recognisable by the astronomer. Such atmospheres not existing, he held that the repulsive force is limited, and that the number of repelling particles must be finite. Faraday found the vapor of bodies formed atmospheres around them of definite dimensions, and hence arrived at a similar conclusion.

It is, perhaps, more advisable to adopt neither hypothesis, but to rest upon experience, for by adopting the view that matter has a limit of divisibility, we adopt a purely theoretic idea, but, at the same time, we cannot avoid making use of the term *particle* of matter, which implies limited divisibility. If, however, we employ the term atom as signifying a mass or collection of particles, we pass over the question entirely, and in this sense, atom, atomic weight express a mass of matter and its weight. To avoid all collision with the question, we employ the terms *equivalent*, *combining weights*, and the term *atom* as an abbreviated expression of the same.

ATOMIC NUMBER. *Chem.* The atomic number of a substance is its specific gravity, divided by its combining weight or equivalent. Let G = spec. grav., E = equivalent, N = atomic number. Employing the term atom as above, the spec. grav. of a substance must be the number of atoms in a given volume, multiplied by their combining weight. $G = NE$, and $N = \frac{G}{E}$ = the atomic number with equal volume. The table given under *AFFINITY* (p. 61), contains in column H the atomic number of several substances in the gaseous state, the gravities being compared with air at 1000. Taking the number 17 for sal-ammoniac, and multiplying by 2, it gives the at. number of chlorohydric acid, nitric oxide, and terchloride of arsenic; $\times$ by 4 = 68, or nearly the at. number of 6 other substances in the table; $\times 4\frac{1}{2}$ = sulphuric acid; $\times 8$ = 136 nearly the at. number of arsenious acid.

ATOMIC THEORY.

The following table of the atomic number of some of the elements, exhibits the close relation between similar bodies.

A	B Comb. Weight.	C Spec. Grav.	D At No. HO = 1.
Nickel.....	29.6	8.6370	0.2918
Manganese....	27.6	8.0000	0.2898
Cobalt.....	29.6	8.5384	0.2885
Iron.....	27.2	7.8439	0.2883
Copper.....	31.8	8.7210	0.2742
Platinum.....	98.7	21.5000	0.2178
Titanium.....	24.5	5.2800	0.2155
Palladium.....	35.4	11.5000	0.2153
Rhodium.....	52.1	11.2000	0.2149
Zinc.....	32.2	6.9154	0.2148
Chrome.....	28.1	5.9000	0.2100
Iridium.....	98.7	18.6300	0.1887
Tungsten ...	95	17.4000	0.1831
Molybdenum...	48	8.6000	0.1792
Tellurium.....	64	6.2580	0.0978
Silver.....	108.1	10.4280	0.0964
Gold.....	199	19.2000	0.0961
Bismuth.....	106.4	9.8220	0.0922
Arsenic.....	75.4	5.9590	0.0792
Phosphorus....	31.4	1.7500	0.0557
Antimony.....	129	6.7010	9.0519
Iodine.....	126	4.9480	0.0393
Bromine.....	78.4	2.9800	0.0380
Chlorine.....	35.4	1.3333	0.0376

Column A. = the elements; B. = their equivalent (H = 1); C. = their spec. grav. (HO = 1); D. = their atomic number, obtained by dividing the spec. grav. by their equivalent. It should be observed that we may regard the equivalents as more accurately determined than the spec. gravs., but possible inaccuracies in the latter cannot conceal the singular relations, developed by the atomic number. These views in reference to the atomic number are more or less dependent on the hypothesis that matter consists of ultimate indivisible particles or atoms. For full tables of the atomic numbers

ATOMIC VOLUME.

of compounds, see *Gmelin's Chem.*, pp. 66—74. See also ATOMIC VOLUME below.

ATOMIC THEORY. *Chem.* The views respecting the combinations of elements in definite proportions were at first more or less hypothetical, and were the foundation of the atomic theory, based upon the idea that matter consisted of ultimate particles, which were indivisible (see the preceding article, *Atom*). These views were successively developed by Wenzel, Higgins, Richter, and Dalton, under the last of whom they received a more substantial and definite form, originating the laws of combination; and although Dalton's views were interwoven with a series of hypotheses, yet, these being separated, and the term atom being understood as explained in the last part of the preceding article, the so-called atomic theory becomes the expression of fact, the fact expressed in the laws of combination, including combination by volume. For a fuller view of these laws, see **COMBINING PROPORTIONS** under the article **AFFINITY**.

ATOMIC VOLUME. *Chem.* This subject has attracted some attention of late, and has been investigated by Kopp and others. Assuming that the volume which a body occupies is entirely filled with atoms (without reference to divisibility), its combining weight is equal to its spec. weight multiplied by the volume of an atom. Let V = volume of atom, E = equivalent, and G = spec. grav.; then $E = VG$, and, since E and G are known, $V = \frac{E}{G}$; or the volume of an atom is found by dividing the equivalent by the spec. grav. Kopp has attained the remarkable result that, in general, "isomorphous bodies have an equal atomic volume;" or, which is the same, "the spec. weights of isomorphous bodies are as their atomic weights," or "the particles (atoms) of isomorphous bodies are equal in form and dimensions." This is shown in the following table of substances, taken chiefly from the mineral kingdom.

	Formula.	Spec. Grav.	Comb. Weight.	Atomic Volume.
{ Gold.....	Au	19.258	2486.	129.08
{ Silver.....	Ag	10.428	1351.6	129.61
{ Binoxide of tin.....	SnO ₂	6.960	935.29	134.38
{ Anatase.....	TiO ₂	3.759	503.69	134.00
{ Ruby.....	Al ₂ O ₃	3.531	642.33	181.93
{ Oxide of iron.....	Fe ₂ O ₃	5.251	978.43	186.33
{ Oxide of chrome.....	Cr ₂ O ₃	5.21	1003.6	192.63

Similar results are attained with the salts, but variations are observable, which bear a remarkable relation with the measured angles of the crystals. Thus, in the four following minerals, carbonates of the right rhombic sys-

tem, taking the relative lengths of the 3 axes as calculated from measurement of the crystals, and taking the average atomic volume, we have the change of form indicated by change of volume.

	Formula.	Ratio of Axes.			Atomic Volume.
		a	b	c	
Witherite.....	BaO.CO ₂	0.7413	: 1	: 0.5950	285.91
White lead.....	PbO.CO ₂	0.7236	: 1	: 0.6100	259.50
Strontianite.....	SrO.CO ₂	0.7237	: 1	: 0.6096	255.53
Arragonite.....	CaO.CO ₂	0.7205	: 1	: 0.6215	213.48

In the carbonates of the hexagonal system, the angles of the rhombs vary from $107^{\circ} 40'$ to $105^{\circ} 5'$, the atomic volume varies from 175 to 231, but

	Formula.	Angle.	At. Vol.
Calamine	ZnO, CO_2	$107^{\circ} 40'$	175.33
Magnesite	MgO, CO_2	$107^{\circ} 25'$	181.25
Mesitin spar	$\frac{1}{2} \left\{ \begin{array}{l} \text{MgO}, \text{CO}_2 \\ \text{FeO}, \text{CO}_2 \end{array} \right\}$	$107^{\circ} 14'$	186.26
Sparry iron	FeO, CO_2	$107^{\circ} 0'$	188.50
Sparry manganese	MnO, CO_2	$106^{\circ} 51'$	202.29
Bitter spar	$\frac{1}{2} \left\{ \begin{array}{l} \text{MgO}, \text{CO}_2 \\ \text{CaO}, \text{CO}_2 \end{array} \right\}$	$106^{\circ} 15'$	202.36
Calcareous spar	CaO, CO_2	$105^{\circ} 5'$	231.20

See Kopp's essays in *Pogg. Ann.* xlvii. *An. der Ch. und Phar.* xxxvi. 1—32, &c., &c.

ATROPIC ACID, ATROPIN. Syn. Atropia. One of the vegetable alkalies or alkaloïds, discovered at the same time, by Geiger and Hesse, and by Mein, in *Atropa Belladonna*, or deadly nightshade. Atropin is found in all parts of the plant.

Prep. According to Geiger and Hesse, watery extract of belladonna, is treated with water, filtered, caustic soda added till it reacts alkaline, and the solution then shaken with one and a half times its own volume of ether, which dissolves the atropin. The treatment with ether is repeated. On evaporation of the ether, the atropin remains mixed with fat and chlorophyl. The residue is then neutralized with dilute sulphuric acid (1 ac. + 9 water) in very slight excess, and the solution treated with so much freshly prepared animal charcoal as just sufficient to leave a yellowish color. The solution is then filtered, and caustic soda added, which precipitates the atropin as a white powder, or in coherent flocks. The filtered solution and the washings deposit, on repose, still more atropin.

The animal charcoal may, for this purpose, be prepared by mixing 5 pts. of fresh blood with 1 pt. of carbonate of potassa, evaporating and igniting it gently till combustible gases are no longer given off. The remaining mass is then boiled, first with water, afterwards with dilute chlorohydric acid, and again washed with water.

According to Mein, 24 pts. of the pulverized root is digested with 60 pts. of alcohol of 90 pr. ct., pressed and again extracted with another portion of alcohol. The filtered solutions are then digested for 24 hours with 1 pt. of slacked lime, previously mixed up with a portion of the liquid, and the solution shaken from time to time. The solution is then filtered, slightly supersaturated with sulphuric acid, and again filtered from the formed precipitate of sulphate of lime. It is then concentrated by distillation to half its original bulk, mixed with 6—8 pts. of water, and the remaining alcohol dissipated by evaporation. The watery solution is then filtered, concentrated to two parts, and, when cold, mixed with so much of a concentrated solution of carbonate of potassa till it becomes turbid from the precipitation of a grayish brown residue, which is allowed to settle, and then separated by filtration. An excess of carbonate of potassa must be carefully avoided, since it would precipitate, at the same time,

some of the atropin. The filtered solution is then mixed with carbonate of potassa in excess, which precipitates the atropin at first gelatinous, but becoming crystalline after the lapse of 24 hours. The precipitate is then separated from the solution by filtration, and, without washing, freed from the mother liquid by pressure between blotting paper, dried, pulverized, and again mixed with a small portion of water and pressed between blotting paper and dried. It is then again pulverized, dissolved by gentle heat in 5 pts. strong alcohol, filtered, and shaken with small portions of animal charcoal, till it is nearly colorless, avoiding, however, an excess, by which it is decomposed. The solution is then filtered, mixed with 6—8 vols. of water, and slowly evaporated, by which the atropin is obtained in crystals. By pressure between filtering paper, and repeated crystallization, it may be obtained perfectly pure. Mein obtained 12 grains of atropin from 12 ounces of belladonna root.

Richter has given the following method. The root is extracted with cold water and the solution fermented for 3 days, by the addition of good yeast, at a temp. of 68° — 77° . The solution is heated to ebullition, filtered, and evaporated to a thin syrupy consistence, and then digested for 24 hours in a closed vessel, with 1 oz. of ammonia and $\frac{1}{2}$ oz. of alcohol of 0.833 for every lb. of the root. The solution is then distilled in a water-bath to the consistency of an extract, dissolved in alcohol of 0.833, and mixed with ammonia till an excess becomes perceptible by the smell. When the whole has been shaken up to a homogeneous mass it is mixed with ether, which precipitates an extractive mass, from which the solution is separated almost colorless, and freed from alcohol and ether by distillation in a water-bath. The residue, which is atropate of atropin, is then treated with ammonia, which extracts the atropic acid, and leaves behind the atropin. The latter is washed with ammoniacal water, dissolved in very dilute sulphuric acid, decolorized by animal charcoal, and precipitated by caustic ammonia.

Prop. Atropin crystallizes, on cooling, from a solution in hot water, in transparent, silky prisms; or, by evaporation from its alcoholic solution, in small needles, resembling sulphate of quinin. By evaporation of its ethereal solution it generally remains as a colorless, transparent mass. It is inodorous, and of a bitter taste. It is a powerful poison when applied to the eye in the minutest quantity. It

dilates the pupil, which state will remain for many days. It is heavier than water, permanent in dry air, has a strong alkaline reaction, fuses at 212° , and sublimes partially at a higher temperature. It is inflammable. Soluble in 200 pts. of cold water, but in 54 pts. hot water, without separating on cooling, but, by continued boiling, it dissolves in 30 pts. of water, from which the greatest part separates on cooling in fine crystals. Soluble in $1\frac{1}{2}$ pts. anhydrous alcohol at ordinary temperature; but in any proportion of hot, from which it partly crystallizes on evaporation, while another portion forms a colorless, gelatinous mass, which holds alcohol in combination. Soluble in 25 pts. cold and 6 pts. boiling ether. Solutions of atropin spoil easily when exposed to the air, and yield, on evaporation, a yellow, uncrystalline mass of strong alkaline reaction and disagreeable characteristic odor, which dissolves in all proportions in water, and out of which carbonate of potassa separates crystals of atropin and an alkaline oily substance, which has not been examined any further. By the presence of the fixed free alkalies, the decomposition is accelerated with the formation of ammonia and a brown, resinous substance. Ammonia and carbonate of potassa seem to have no further effect than water. Acids rather prevent its decomposition. Animal charcoal acts on it as the fixed alkalies, decomposing it even at ordinary temperature, and still faster by heating. Atropin is precipitated by a solution of tannin.

According to Liebig, atropin consists of

	Atoms.	In 100 parts.
Carbon	34	70.98
Hydrogen.....	23	7.83
Nitrogen.....	1	4.83
Oxygen.....	6	16.36

Berzelius expresses its formula by $\text{NH}_3 + \text{C}_{34}\text{H}_{20}\text{O}_6$, and its symbol by $\square_{\text{At}}$.

Salts of Atropin.

Atropin is capable of neutralizing the diluted acids, combining with them to neutral salts, of which the greater part may be obtained in crystals on evaporation. They are all distinguished by the peculiar taste of the atropin. When pure, they are inodorous, permanent in the air, and most of them soluble in water, alcohol, and a mixture of alcohol and ether, but not in pure ether. In solution they keep tolerably well, at ordinary temperature, when pure, but decompose rapidly by heat. Iodine produces a brown precipitate in their solution, and the chlorides of gold and platinum a yellow, that by the former becoming crystalline. Animal charcoal decomposes them. The salts of atropin have the same therapeutical effect as atropin itself, and are likely to become of importance in medicine.

Chlorohydrate of Atropin, obtained by saturating dilute chlorohydric acid with atropin, and evaporating the solution at a gentle heat, crystallizes in groups of small needle-shaped crystals, permanent in the air, and easily soluble in water and alcohol.

Sulphate of atropin is obtained in similar

crystals of great lustre, permanent, and very soluble.

Nitrate of atropin forms a gum-like mass, deliquescent by exposure.

Tartrate of atropin similar to the previous.

Acetate of atropin obtained in permanent, easily-soluble crystals. By evaporation it leaves part of its acetic acid.

Atropic acid. According to Richter, atropin occurs combined in *Atropa Belladonna*, with an acid, which he has called atropic acid. It has already been mentioned that the last residue in the preparation of atropin, according to Richter's method, consisted of atropate of ammonia, from which the atropic acid was extracted by ammonia. This solution of atropate of ammonia is mixed with potassa, and evaporated till all ammoniacal vapors are expelled. The solution is then discolored with animal charcoal, evaporated to dryness, and treated with dilute sulphuric acid, after which the solution is evaporated to crystallization. The acid is thus obtained in long, pointed crystals, which, like benzoic acid, may be sublimed without decomposition, but yield no red precipitate with salts of iron.

ATTRACTION (*Ad, to, traho, to draw*). The fact that two masses, or particles of matter, tend to approach each other, or to resist their disjunction; which is often expressed, for convenience, as a property of matter; thus, magnetized iron is said to have the property of attracting iron or steel. The attractive forces may be thrown into two groups, according as they are exerted between particles or masses of matter.

I. External forces acting upon masses of matter at sensible distances.

1. *Gravity*, which is exerted between the same or different kinds of matter, often at very great distances. Thus a stone put at liberty above the earth, descends to it by the attraction of gravitation; and the same force retains the planets in their orbits.
2. *Electricity*. Many bodies by friction are capable of attracting light bodies of various kinds of matter, as when glass, sealing-wax, &c., are rubbed by silk, wool, &c., they attract pieces of paper, pith, &c. Electricity may be developed by chemical action, as when zinc and copper are placed in juxtaposition in an acidulated liquid medium.
3. *Magnetism*. An attractive force exhibited between iron and some of its compounds, previously prepared by electric action, &c.

II. Internal forces, acting between the molecules or particles of matter at insensible distances, called also molecular forces.

1. *Cohesion*, exerted between like matter, and hence called homogeneous attraction cohesive force. Thus two plane and polished surfaces of lead, glass, &c., will adhere so as to require a considerable force for their separation. The various states and degrees of solid, viscid, and liquid, are more or less in proportion to the amount of their cohesive force.

ATTAR.

AUGITE.

2. *Adhesion*, a similar force to cohesion, exhibited between unlike matter, and hence sometimes called Heterogeneous adhesion. Thus the rise of water on the vertical surface of glass, in capillary tubes; the absorption of gases and liquids by charcoal.
3. *Solution*. Allied both to the preceding and the following force, and exerted between different kinds of matter, with a resulting change in the state of one of the kinds of matter. Thus, when salt is dissolved in water, it passes from the solid into the liquid state.
4. *Affinity*. The term may mean any kind of attraction, but is generally limited to that variety which is exerted between different kinds of matter, uniting them into a new body, possessed of properties essentially different from those of its constituents.

The evident transition or gradation between these four molecular forces, will probably throw them into one capable of four or more modifications. For fuller views respecting them, consult the several articles in the present work.

ATTAR. See Oil of Roses.

AUGITE. *Min.* Pyroxene; Paratomous Augite-spar, *Mohs.* (See Varieties below.)

Descrip. Cryst. Oblique Rhombic system; the vert. prism M on M = $87^{\circ} 5'$; M on back end-plane = $101^{\circ} 5'$, front adjacent octahedral planes = $81^{\circ} 46'$, back 8-hedral planes = 120° . The prevailing combinations are the vert. prism, with 1st and 2d lateral planes on its edges, the octahedral planes with the base and back terminal planes on their edges; the prisms are often terminated by two planes of an oblique prism alone. Cleavage parallel to M and to 1st and 2d lateral planes. Twins parallel to 1st lateral plane. It occurs sublamellar, granular, either loosely aggregated or very coherent.

H. = 5 — 6. G. = 3.233 = 3.4.

Color, various shades of green, passing into white and black; lustre usually vitreous; transparent, opaque; streak white, gray; brittle; fracture conchoidal, uneven.

Behavior. From the replacement of isomorphic bases, the reactions are variable before the blowpipe.

1. *Diopside*, from Piemont; white *Malacolite*, from Tammare in Finland, &c.; light green *Salite*, from Sala. They fuse to a colorless, translucent glass, giving off some bubbles; borax dissolves to a clear glass; slowly soluble in mic. salt, leaving a skeleton of silica, and opalescing on cooling. Diopside dissolves with the greatest difficulty; malacolite from

Björmyresweden gives an iron reaction. With a little soda they form a very fusible clear glass, with more soda, difficultly fusible and translucent; cobalt solution colors diopside and the Finland malacolite red, the malacolite from Tjötten bluish.

2. *Hedenbergite* from Tunaberg; dark-green *Augite* from Taberg and Arendal; dark-red *Malacolite* from Dagerö in Finland. They yield in a closed tube acid hygroscopic water. fuse in the forceps, with a little boiling, to a shining black glass. Their behavior to borax and mic. salt is similar to the preceding (1), but they give a strong iron reaction; with soda they form a black glass, and with more soda the glass becomes dull on the surface.

3. Common *Augite* from Pargas and from volcanic rocks. Behavior similar to foregoing, but mic. salt scarcely decomposes it. With soda, these aluminous augites form a glass of more difficult fusibility than the dark-green varieties highly charged with iron.

4. *Diallage*. In a closed tube yields neutral water, decrepitates, and becomes lighter colored; on charcoal fuses on the edges with difficulty to a gray slag, and in thin laminae to a shining, blackish green glass; dissolves in borax and mic. salt with iron reaction, leaving a skeleton of silica in the latter; with a little soda fuses to a translucent, grayish green bead, and with more soda is infusible; with soda on platinum foil gives the reaction of manganese.

5. *Hypersthene*. In a closed tube behaves like 4, without changing color; fuses readily on charcoal to a translucent, grayish green glass; it appears not to be attacked by mic. salt, but is rounded on the edges. Small splinters fuse in forceps to a greenish black magnetic glass, but some varieties are almost infusible.

All varieties of augite, whether fused or not, are imperfectly decomposed by acids.

Analysis. They are thrown into several divisions by Rammelsberg, according to the prevailing character of the constituents.

I. Augites containing no Alumina.

1. *Calcareo-magnesian Augites*. 1. Diopside from the Mussa Alp, by Laugier; 2. bluish green Augite from Pargas, by Nordenskiöld; 3. Diopside from Tammare in Hwittis in Finland, by Bonsdorff; 4. greenish Salite from Sala, Sweden; 5. white Malacolite from Orri-erfvi in Finland; and, 6. a yellowish from Langbanshytta in Wärmeland, by H. Rose; 7. white Malacolite from Tjötten in Norway, by Trolle-Wachtmeister; 8. the same as 6, by Hisinger.

	1.	2.	3.	4.	5.	6.	7.	8.
Silica	57.50	55.40	54.83	54.86	54.64	55.32	57.40	54.18
Lime	16.50	15.70	24.76	23.57	24.94	23.01	23.10	22.72
Magnesia	18.25	22.57	18.55	16.49	18.00	16.99	16.74	17.81
Protox. of iron } 6.00		2.50	0.99	4.44	1.08	Fe ₂ O ₃ = 2.16	0.20	1.45
Protoxide of manganese } 2.83		Mn ₂ O ₃ = 0.32	0.42	2.00	1.59	—	2.18	
Alumina	(Mn ₂ O ₃ = 0.43)	0.28	0.21	—	—	0.43	(1.20)	
	98.25	99.43	99.73	99.99	100.66	99.07	97.87	99.54

The 1.20 in the 8th column is loss by ignition.

AUGITE.

2. *Calcareo-ferrous Augites*. 1. Hedenbergite from Tunaberg in Södermanland; 2. black crystal. Augite from Taberg in Würmland, both by H. Rose; 3. green Augite from Lake

	1.
Silica.....	49.01
Lime	20.87
Magnesia.....	2.99
Protoxide of iron	26.08
Protoxide of manganese.....	—
	98.94

The 1.83 in the 3d is alumina, and the 0.90 in the 4th is loss by ignition.

3. *Calcareo-manganesian Augite*, or Red Silicate of Manganese, from Långbanshytta, by Berzelius.

Silica.....	48.00
Lime.....	3.12
Magnesia.....	0.22
Protoxide of manganese.....	40.04
	100.38

4. *Ferro-manganesian Augites*. 1. Bisilicate of manganese, and 2. Sesquisilicate of Manganese, both from Franklin, New Jersey, and by Thompson:

	1.	2.
Silica.....	40.58	42.40
Protoxide of iron..	13.50	6.76
Protox. of mangan.	38.92	50.72
Carbonic acid	3.23	—
Water	2.00	—
	99.23	99.88

The 1st, according to the analysis, is nearly a $\frac{2}{3}$ silicate, and the 2d scarcely admits of

	1.	2.	3.	4.	5.	6 a.	b.	7.
Silica.....	51.80	50.73	50.90	50.55	50.09	47.05	49.39	48.00
Lime	19.07	18.90	22.96	22.29	20.53	23.77	22.46	24.00
Magnesia	12.01	16.91	14.43	13.01	13.93	15.35	13.93	8.75
Protox. of iron..	6.92	7.26	6.25	7.96	11.16	7.57	7.39	$\text{Fe}_2\text{O}_3=12.00$
Alumina.....	6.56	6.47	5.37	4.85	4.39	5.16	6.00	5.00
Water	1.02	—	—	—	—	—	—	$\text{Mn}_2\text{O}_3=1.00$
	97.28	100.27	99.91	98.66	100.10	98.90	99.25	98.75

2. *Diallage (Bronzite)*. 1. Diallage from the Harz; 2. a variety from Salzburg; 3. from Prato near Florence; 4. crystallized from Baste; 5. Bronzite from Olivine of the Basalt

Champlain, United States, by Seybert; 4. reddish brown Malacolite from Dagerö in Finland, by Berzelius.

	1.	2.	3.	4.
Silica.....	53.36	50.38	50.00	50.00
Lime	22.19	19.33	20.00	20.00
Magnesia.....	4.99	6.83	4.50	4.50
Protoxide of iron	17.38	20.40	18.85	18.85
Protoxide of manganese.....	0.09	trace	3.00	3.00
		(1.83)	(0.90)	(0.90)
	98.01	98.77	97.25	97.25

a formula, the nearest to which would be $12 \text{FeO} + 7 \text{SiO}_3$.

5. *Calcareo-manganesian ferrous Augite*. 1. Green Malacolite from Björmyresweden in Dalecarlia, 2. a similar variety from the same, both by H. Rose; 3. Malacolite, from the same, by d'Ohsson.

	1.	2.	3.
Silica.....	54.08	54.55	57.28
Lime	23.47	20.21	24.88
Magnesia.....	11.49	15.25	9.12
Protox. of iron	10.02	8.14	6.04
Oxide of mang., Mn_2O_3	0.61	0.73	0.72
Alumina.....	—	0.14	—
	99.67	99.02	98.04

II. Aluminous Augites.

These are chiefly of volcanic origin, and include Diallage, Bronzite, Hypersthene, and Paulite.

1. *Augites*. 1. Brown from Pargas, by Nordenskiöld; 2. from the Rhön mountains; 3. from lava of Vesuvius; 4. from Etna; 5. from the Augite porphyry of Zigelonberg in Fassa valley; 6. from Gillenfelder Maar in the Eifel: 2—6, by Kudernatsch; 7. from Frascati, by Klaproth.

	1.	2.	3.	4.	5.	6 a.	b.	7.
Silica.....	51.80	50.73	50.90	50.55	50.09	47.05	49.39	48.00
Lime	19.07	18.90	22.96	22.29	20.53	23.77	22.46	24.00
Magnesia	12.01	16.91	14.43	13.01	13.93	15.35	13.93	8.75
Protox. of iron..	6.92	7.26	6.25	7.96	11.16	7.57	7.39	$\text{Fe}_2\text{O}_3=12.00$
Alumina.....	6.56	6.47	5.37	4.85	4.39	5.16	6.00	5.00
Water	1.02	—	—	—	—	—	—	$\text{Mn}_2\text{O}_3=1.00$
	97.28	100.27	99.91	98.66	100.10	98.90	99.25	98.75

from Stempel near Marburg in Hessa; 6. Bronzite from the Seefeld Alp in Ulenthal, Tyrol: 1—6, by Köhler; 7. Bronzite from Kravbat in Styria, by Klaproth.

	1.	2.	3.	4.	5.	6.	7.
Silica.....	53.707	51.338	53.200	53.739	57.193	56.813	60.0
Lime.....	17.065	18.284	19.088	4.729	1.299	2.195	—
Magnesia.....	17.552	15.692	14.909	25.093	32.669	29.677	27.5
Protox. of iron....	8.079	8.230	8.671	11.510	7.461	8.464	$\text{Fe}_2\text{O}_3=10.5$
Protox. of mangan.	0.380	0.233	0.349	0.616	—	—	—
Alumina.....	2.825	4.388	2.470	1.335	0.698	2.068	—
Water.....	1.040	2.107	1.773	3.758	0.631	0.217	0.5
	100.268	100.039	100.491	100.397	100.300	100.050	98.5

AUGITE.

AUGITE.

Regnault examined Diallage with similar results, as the following analyses show:

	1.	2.	3.	4.	5.
Silica.....	51.25	50.05	56.41	52.60	55.84
Lime	11.18	15.63	—	20.44	—
Magnesia.....	22.88	17.24	31.50	16.43	30.37
Protox. of iron	6.75	11.98	6.56	5.35	10.78
Protox. of manganese	—	—	3.30	—	—
Alumina.....	3.98	2.58	—	3.27	1.09
Water	3.32	2.13	2.38	1.59	1.80
	99.36	99.61	100.15	99.68	99.88

3. *Hypersthene (Paulite)*. 1. Hypersthene from island of St. Paul, Labrador; 2. from the island of Skye; 3. from Baffin's Bay (in quartz); 1—3. by Muir; 4. from Labrador, by Klaproth.

	1.	2.	3.	4.
Silica.....	46.112	51.348	58.272	54.25
Lime	5.380	1.836	—	1.50
Magnesia.....	25.872	11.092	18.960	14.00
Protox. of iron	12.701	33.924	14.416 Fe ₂ O ₃ =	24.50
Protox. of manganese.....	5.292	—	6.336	trace
Alumina.....	4.068	—	2.000	2.25
Water	0.480	0.500	—	1.00
	98.905	98.700	99.984	97.50

From all the analyses of Augites, the oxygen of the silica being always twice that of the bases, the conclusion follows that they are $\frac{2}{3}$ silicates (or $\frac{1}{3}$ basic), and their formula is $3RO, 2SiO_3$, in which R is calcium, magnesium, iron, and manganese. The frequent presence and quantity of alumina is almost inexplicable, for it cannot well be added to the silica, nor omitted as unessential; nor can it well be viewed as belonging to the mother-liquor, enclosed during the crystallization of the augite.

The augites may be divided, in reference to the prevailing bases, into

1. Those containing chiefly lime and magnesia, with a formula, $3 \left\{ \begin{smallmatrix} CaO \\ MgO \end{smallmatrix} \right\} 2 SiO_3$, in which the two bases are generally present in equal equivalents, so that their formula would be $(3CaO, 2SiO_3) + (3MgO, 2SiO_3)$. They are generally light-colored.

2. Augites containing chiefly lime and protoxide of iron $3 \left\{ \begin{smallmatrix} CaO \\ FeO \end{smallmatrix} \right\} 2 SiO_3$. In Hedenbergite these bases are in equal equivs., and have the form., $(3CaO, 2SiO_3) + (3FeO, 2SiO_3)$.

3. Those with lime and protoxide of manganese, in which the manganese appears almost to exclude other bases, and would then give the formula, $3MnO, 2SiO_3$.

4. Those with protoxides of iron and manganese, 3 equivs. of the latter to 1 eq. of the former.

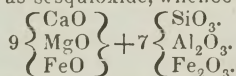
5. Those containing all the above bases, in which may be included the aluminous varieties.

In the varieties hitherto examined, there are certain limits in the ratio of the bases, the magnesia varying between 6 and 17 per cent., the lime between 18 and 25, and protoxide of iron between 6 and 12. Notwithstanding these fluctuations, the greater number of analysis give 2 eq. magnesia to 3 eq. lime, and 1 eq. protoxide of iron, whence the formula set up by Berzelius, $3(3CaO, 2SiO_3) + 2(3MgO, 2SiO_3) + (3FeO, 2SiO_3)$.

Diallage has all the bases, but, in reference to their ratio, consists of two divisions: 1. those containing much lime; and, 2. those containing little or no lime. The former = $3MS_2 + 2CS_2 + fS_2$, and the latter $3MS_2 + fS_2$.

Hypersthene seems to belong to the latter division of diallage, containing only small quantities of lime. Berzelius deduced from Klaproth's analysis, $MgS_2 + fS_2$.

Gerhardt views augite and hornblende as $\frac{2}{3}$ silicates and aluminates, assuming a portion of the iron as sesquioxide, whence his formula,



Addenda. Rammelsberg investigated several pseudomorphs of augite, or matter, which has replaced crystals of augite, with the following results. 1. A yellow, clayey mass from the neighborhood of Bilin; 2. whitish crystals from Vesuvius, often enclosing a portion of less-altered augite; 3. green pseudomorph of augite (green earth) from Fassathal:

	1.	2.	3 a.	b.
Silica	60.626	85.34	45.87	39.48
Alumina	23.085	1.58	11.18	10.31
Peroxide of iron.....	4.207	1.67	—	8.94
Protoxide of iron	—	—	24.63	15.66
Magnesia.....	0.910	1.70	0.28	1.70
Lime.....	1.275	2.66	1.50 CaO, CO ₂ =	15.24
Alkali	—	—	6.72	} 8.67
Water.....	9.124	5.47	0.82	
	99.227	98.42	100	100

The bases of 1 are nearly removed, with a portion of silica; in 2 this is still more the case, probably on account of the stronger acids developed by the volcano. It is difficult to explain the presence of alkali in 3, except by infiltration.

Localities, &c. Augite is usually found in basalt, granite, greenstone, lavas, and similar rocks. The following are among the names applied to this protean mineral species. Augite and Pyroxene apply as specific terms to the several varieties. *Augite* (ἀυγή, lustre) from the generally superior lustre of augite to hornblende; *Pyroxene* (πῦρ, fire, ξένος, stranger) from its occurrence in lavas to which it did not belong, *Haüy*; *Diopside* (διά, through, ὀπταῖα, to look) from its being sometimes transparent, found at Ala (hence called *Alalite*) and the Mussa Alp (hence also *Mussite*), generally light-colored, with a shade of green; transparent, translucent; associated with precious garnet; at Heiligenblut in Carinthia; from Schwarzenstein in Tyrol, often of two colors (hence *Proteïte*); Reichenstein, Silesia; Lake Baikal, Siberia, &c., &c.; *Salite* imperfectly crystallized and light green, found at Sala in Sweden; *Baikalite* from Lake Baikal, and *Fassaita* from Fassathal are dingy green varieties; White *Malacolite* in Finland, Norway, &c. (see behavior and analysis above); *Omphazite*, a foliated leek-green variety; *Coccolite* (κικκος, seed) is applied to the granular varieties; the granules are rounded or angular; *Diallage* usually grass or emerald-green (hence *Smaragdite* or emerald-stone); *Hypersthene* (ὑπερ, above, σθένος, strength) from its difficult fragility, found among other localities at St. Paul's Island, Labrador, whence *Paulite* and *Labrador Hornblende*; *Bronzite*, from its peculiar play of light.

The American localities are Bytown, Lower Canada, large, white, subtransparent in calcareous spar; less clear in Canaan, Connecticut, in Dolomite; at Kingsbridge, New York; at Bolton, Massachusetts; salite at New Haven and Milford, Connecticut, at Bolton, Massachusetts, and Monroe, New York; coccolite at Willsborough, New York, in granite, associated with garnet and tabular spar, and under similar circumstances in Bucks county, Pennsylvania. Massive augite at Rogers' Rock on Lake George. Hypersthene occurs with chondrodite at Warwick, New York; in feldspathic rock at Dupont's works on the Brandywine, Delaware, &c., &c.

AURADE. See ORANGE-flower-camphor.

AURANTIIN. See HESPERIDIN.

AURATES, AURIC ACID. See GOLD.

AURICHALCITE. *Min. Descrip.* Small, broad-columnar pieces, partly forming sharp granules imbedded in limestone and brown hematite, partly as a drusy coating. Color verdigris-green; lustre pearly; translucent; H. = 1.

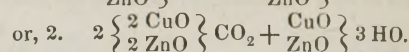
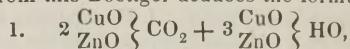
Behavior. In closed tubes yields neutral water, changing to brownish black; in the reducing flame on charcoal, coats the latter white without fusing; moistened with cobalt solution in the oxidizing flame, the coating green after cooling; soluble in borax and mic. salt with effervescence to a green copper-glass; mixed with equal quantities of borax and soda, it gives, in the reducing flame, a strong coating

of oxide of zinc and a metallic button of copper. Wholly soluble with effervescence in chlorohydric acid.

Analysis, both by T. Boettger:

Oxide of copper	28.192	28.357
Oxide of zinc	45.839	45.620
Carbonic acid	16.056	16.077
Water	9.950	9.933
	100.037	99.987

From this Boettger deduces the formulæ,



The former (1) resembles the formula of Blue Malachite in which oxide of zinc replaces oxide of copper.

Locality. Loktewsk and other copper mines in the Altai mountains.

AURIPIGMENTUM. *Min.* See ORPIMENT.

AUTOMALITE. *Min.* See GARNITE.

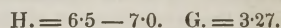
AVENTURINE. *Min.* See QUARTZ.

AVENTURINE GLASS. See GLASS.

AXE-STONE. *Min.* See JADE.

AXINITE. *Min. Syn.* Thumite, Thumstein, Yanolite.

Descrip. Cryst. system, Doubly Oblique Rhombic. Terminal plane or base on the main vertical prism = 134° 40'. The crystals are flat, with many intermediate planes, forming very obtuse angles. Cleavage imperfect. It occurs also with a slightly-curved lamellar structure, and rarely granular.



Color usually clove-brown, inclining to lead blue and pearl-gray, sometimes yellow and green from the presence of chlorite; rarely almost colorless; lustre vitreous, brilliant; transparent, subtranslucent; streak white; brittle; small conchoidal fracture.

Behavior. Fuses readily, with puffing, to a shining, dark-green glass, which becomes black in the oxidizing flame; easily dissolved by borax to a glass colored with iron, which, by long exposure to the oxidizing flame, becomes amethystine, sooner by adding saltpeter to the hot bead; it leaves a skeleton of silica in mic. salt; with soda it becomes at first green, then fuses to a black glass with an almost metallic lustre; with soda on platinum foil, gives a strong manganese reaction; according to Turner, it gives the green flame of boracic acid with bisulphate of potassa and fluor spar. Rammelsberg could not obtain the last reaction.

It is scarcely acted on by chlorohydric or sulphuric acid; but, if fused and pulverized, the former decomposes it perfectly, separating gelatinous silica.

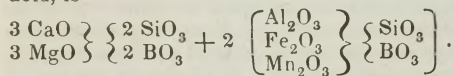
Analysis. 1. From Oisans, Dauphiné, by Vauquelin; 2. from the same; 3. from Treseburg; 4. from Berkutzkaja-gora near Miask in the Ural: 2—4, by Rammelsberg; 2 a, 3, and 4 were fused with carbonate of soda; b was fused alone, then decomposed by chlorohydric acid; c by fluohydric acid; the boracic acid in the latter was separately determined by fusion with carbonate of soda.

AXIS.

BALANCE.

	1.	2a.	b.	c.	3.	4.
Silica	44	43.465	43.676	—	43.736	43.720
Alumina	18	16.299	15.630	17.170	15.660	16.923
Peroxide of iron.....	14	10.249	9.454	9.308	11.940	10.210
Oxide of manganese, Mn ₂ O ₃	4	2.737	3.048	2.939	1.369	1.158
Magnesia	—	1.545	1.703	1.940	1.774	2.213
Lime.....	19	19.904	20.671	19.998	18.900	19.966
Potassa	—	—	0.637	0.112	} 6.621	5.810
Boracic acid.....	—	—	5.609	3.401		
	99		100.428		100	100

In 3 and 4 the alkali, boracic acid, and loss are given together. The formula deduced from the analyses, with 4.5 as the average of boracic acid, is



or, more generally, by using R for metal and X for the acid radical, 3 RO, 2 XO₃ + 2 (R₂O₃, XO₃).

Localities, &c. Axinite from *αξων*, an *axe*, from the sharp edges of its crystals and their resemblance to an *axe*. It occurs at Thum in Saxony (whence Thumite), at Schneeberg, Schwarzenberg; at Treseberg on the Harz in clay-slate; at Monzoniberg in Tyrol; at Barèges in the Pyrenees in quartz, &c. The finest crystals occur near D'Oisans in Dauphiné; at Botallack near Land's End in Cornwall; Kongsberg, Norway.

AXIS. *Phys.* A word employed in various sciences, and in the arts, which has consequently various significations. In physics it usually denotes a line or direction bearing a certain relation of position and other peculiarities to other lines or directions. Thus in crystals we have crystallographic, optical, and thermal axes, which may or may not coincide. See CRYSTALLOGRAPHY.

AZO, or AZ. *Chem.* A prefix to many organic bodies containing nitrogen, which are derived from the action of nitric acid. Thus, Azoleic, Azeleic acids, for which, see OLEIC ACID; Azobenzide, see under BENZYL; Azomarine acid, see common RESIN, &c., &c.

AZOTANE. *Chem.* See Chloride of NITROGEN.

AZOTE. *Chem.* A synonyme of NITROGEN.

AZOTIC ACID. *Chem.* A synonyme of Nitric acid.

AZULMIC ACID. *Chem.* See Cyanohydric acid under CYANOGEN.

AZURE-MALACHITE. *Min.* See BLUE MALACHITE.

AZURE-STONE. *Min.* See HAUYNE.

AZURITE. *Min.* See LAZULITE.

B.

BABINGTONITE. *Min.* Syn. Axotomous Augite-Spar, *M.* Babingtonite, *Levy*.

Descrip. Cryst.-system, Doubly Oblique Rhombic. The terminal plane P on one vert. plane M = 92°34', on another T = 88°. Cleaves perfectly parallel to P, less to T.

H. = 5.5 — 6. G. = 3.4 — 3.5.

Color greenish black, in thin laminæ parallel to P, slightly translucent and brown, perpen-

dicular to it green; lustre vitreous, brilliant; fracture subconchoidal.

Behavior. Fuses on the surface into a black enamel; with borax gives a violet (orange ?) bead, which becomes green in the reducing flame.

Analysis. Of Babingtonite from Arendal, in Norway, by Arppe.

		Oxygen.
Silica	54.4	= 28.27
Lime.....	19.6	5.50
Magnesia	2.2	0.85
Protox. of mang.,.	1.8	0.40
Protoxide of iron..	21.3	4.85
Alumina	0.3	—
Loss by ignition...	0.9	—
	100.5	

Including the magnesia and protoxide of manganese in the protoxide of iron, the formula is CaO, SiO₃ + 3 FeO, 2 SiO₃; or neutral silicate of lime + $\frac{3}{2}$ protosilicate of iron, which is the formula of Hornblende in part. Arppe first extracted titaniferous iron with a magnet, and could then find no trace of titanium, which Children had detected in it.

Localities. It occurs well crystallized at Arendal in Norway, associated with epidote and massive garnet; in the Shetland isles in white quartz.

It is remarkable that, with a similar composition to Hornblende, it should belong to a different crystal system, which throws some doubt either on the examination of the crystal or on the analysis. See HORNBLende. (*Berz. Jahresb.* xxii. 205.)

BAKALITE. *Min.* See AUGITE.

BALANCE. *Ger.* Waage. An instrument for the determination of the relative weight of bodies, compared with other bodies assumed as standards, and which are called weights (see WEIGHTS). The balance is one of the most important chemical instruments, and a knowledge of the principles on which it acts is absolutely indispensable to the chemist. But, as the full development of these principles belongs altogether to another branch of science, we shall content ourselves with a concise exposition of them.

The balance may be considered as consisting of a lever called the beam, furnished with three axes, one the fulcrum or centre of motion, situated in the middle, by which it is supported horizontally, and upon which it turns in a vertical plane, the other two near its extremities, on which are suspended the pans or scales, which receive the weights and the body to be weighed.

Let Figure 1, Pl. V., represent a section of a balance beam, and c its centre of gravity. It is evident that if the axis of support passed through this point, the beam would remain at rest in any position in which it might be placed. In order, therefore, to keep the beam in the horizontal position, it is necessary that the support should be in a point perpendicular over its centre of gravity as in d . The beam will then not only remain in the horizontal position, but if its horizontality be in any way disturbed, its centre of gravity will tend to resume its former lowermost position in the perpendicular line from d , and thus cause the beam through a number of oscillations to resume its horizontal position.

Now let a and b represent the points where the pans are suspended. The weights in the pans may then be considered as weights added in these points. For simplicity, let the lever be considered as inflexible, and the line of suspension, ab , which unites the two points of suspension of the pans, be supposed to pass through the point of support or the fulcrum d , and the arms of the lever ad and db to be equal. We have then the weight of the balance constituted by two parts, the weight of the beam, which is constant and represented by its centre of gravity, c , and the weight of the pans varying by the additional weights added to them. If the weight of the pans be equal, their centre of gravity will be in d , and remain in this point by the addition of any amount of equal weights on both sides. The centre of gravity of the balance, which results from the weight of the beam represented by c and the weight of the pans represented by d , must therefore be somewhere in the line dc , and the only effect of adding equal weights in the pan will be to move the resulting centre of gravity of the whole balance nearer towards d , which it never can reach. The beam will therefore, by the addition of equal weights in both pans, remain in its horizontal position, or, if disturbed, tend to assume it.

But, instead of equal, if unequal weights be added in the two pans so that, for instance a larger weight will act in b than in a , it is evident that their centre of gravity will be removed from d in the line ab towards that pan in which is the heavier weight, for instance to e ; the resulting centre of gravity of the whole balance will then no longer be between d and c , but between e and c , for instance in g . This point will therefore tend to take its position perpendicularly below the support d , and thereby cause the beam to deviate from the horizontal position, and, after a number of oscillations, to settle in a state of rest, forming an angle with the horizon, as represented in Fig. 2. The extent of this angle is a measure of the delicacy or sensibility of the balance.

As the sensibility of a balance is of the utmost importance in nice scientific inquiries, we shall enter into a consideration of the circumstances by which this property is influenced.

In Fig. 3, Pl. V. let AB represent the beam drawn from the horizontal position by a very small weight placed in the scale suspended from the point B ; then the force tending to

draw the beam from the horizontal position may be expressed by PB multiplied by such very small weight acting upon the point B .

Let the centre of gravity of the whole be at G ; then the force acting against the former will be GP multiplied into the weight of the beam and scales, and when these forces are equal, the beam will rest in an inclined position. Hence we may perceive that as the centre of gravity is nearer to or further from the fulcrum S (every thing else remaining the same), the sensibility of the balance will be increased or diminished.

For, suppose the centre of gravity were removed to g , then to produce an opposing force equal to that acting upon the extremity of the beam, the distance, gp , from the perpendicular line must be increased until it becomes nearly equal to GP ; but for this purpose the end of the beam B must descend, which will increase the angle HSB .

As all weights placed in the scales are referred to the line joining the points of suspension of the scales, and as this line is above the centre of gravity of the beam when not loaded, such weights will raise the centre of gravity; but it will be seen that the sensibility of the balance, as far as it depends upon this cause, will remain unaltered.

For, calling the distance SG unity, the distance of the centre of gravity from the point S (to which the weights which has been added is referred) will be expressed by the reciprocal of the weight of the beam so increased; that is, if the weight of the beam be doubled by weights placed in the scales, Sg will be one-half of SG ; and if the weight of the beam be in like manner trebled, Sg will be one-third of SG , and so on. And as GP varies as SG , gp will be inversely proportionate to the increased weight of the beam, and, consequently, the product obtained by multiplying gp by the weight of the beam and its load will be a constant quantity, and the sensibility of the balance, as before stated, will suffer no alteration.

We will now suppose that the fulcrum S , Fig. 4, is situated below the line joining the points of suspension, and that the centre of gravity of the beam when not loaded is at G . Also, that when a very small weight is placed in the scale suspended from the point B , the beam is drawn from its horizontal position, the deviation being a measure of the sensibility of the balance. Then, as before stated, GP , multiplied by the weight of the beam, will be equal to $P'B$ multiplied by the very small additional weight acting on the point B .

Now, if we place equal weights in both scales, such additional weights will be referred to the point W , and the resulting distance of the centre of gravity from the point W , calling WG unity, will be expressed as before by the reciprocal of the increased weight of the loaded beam. But GP will decrease in a greater proportion than WG : thus, supposing the weight of the beam to be doubled, Wg would be one-half of WG ; but gp , as will be evident on an inspection of the figure, will be less than half of GP ; and the same small weight which was before applied to the point B , if now added, would depress the point B , until the distance

gp became such as that, when multiplied by the weight of the whole, the product would be as before equal to $P'B$, multiplied by the before-mentioned very small added weight. The sensibility of the balance, therefore, in this case would be increased.

If the beam be sufficiently loaded, the centre of gravity will at length be raised to the fulcrum S , and the beam will rest indifferently in any position. If more weight be then added, the centre of gravity will be raised above the fulcrum, and the beam will turn over.

Lastly, if the fulcrum S , Fig. 5, is above the line of suspension, as any additional weights placed in the scales will be referred to the point W , in the line adjoining A and B , if the weight of the beam be doubled by such added weights, and the centre of gravity be consequently raised to g , Wg will become equal to half of WG . But gp being greater than one-half of GP , the end of the beam B will rise until gp becomes such as to be equal, when multiplied by the whole increased weight, of the beam to $P'B$, multiplied by the small weight, which we suppose to have been placed as in the preceding examples, in the scale.

From what has been said, it will be seen that there are three positions of the fulcrum which influence the sensibility of the balance: first, when the fulcrum and the points of suspension are in a right line, when the sensibility of the balance will remain the same, though the weight with which the beam is loaded should be varied; secondly, when the fulcrum is below the line joining the two points of support, in which case the sensibility of the balance will be increased by additional weights, until at length the centre of gravity is raised above the fulcrum, when the beam will turn over or *set*; and, thirdly, when the fulcrum is above the line joining the two points of support, in which case the sensibility of the balance will be diminished as the weight with which the beam is loaded is increased.

The sensibility of a balance, as here defined, is the angular deviation of the beam occasioned by placing an additional constant small weight in one of the scales; but it is frequently expressed by the proportion which such small additional weight bears to the weight of the beam and its load, and sometimes to the weight the value of which is to be determined.

This proportion, however, will evidently vary with different weights, except in the case where the centre of gravity of the beam is in the line joining the points supporting the scales, the fulcrum being above this line, and it is therefore necessary, in every other case, when speaking of the sensibility of the balance, to designate the weight with which it is loaded: thus, if a balance has a troy pound in each scale, and the horizontality of the beam varies a certain small quantity, just perceptible on the addition of one-hundredth of a grain, we say that the balance is sensible to $\frac{1}{10000}$ part of its load with a pound in each scale, or that it will determine the weight of a troy pound within $\frac{1}{375000}$ part of the whole.

The nearer the centre of gravity of a balance is to its fulcrum, the slower will be the oscillations of the beam. The number of oscillations,

therefore, made by the beam in a given time (a minute for example), affords the most accurate method of judging of the sensibility of the balance, which will be the greater as the oscillations are fewer.

An active chemist generally requires two or three balances; for large quantities, if weighed in balances of great delicacy, would infallibly injure, or even destroy them, by flexure of the beam, or change in the points of support; and minute differences in small weights cannot usually be appreciated in scales intended for great quantities, because of the strength it is necessary to give the instrument, and the consequent weight and comparative roughness of the parts. One pair of scales should therefore be provided for larger weights, such as from one ounce up to three or four pounds, or even more, and be so constructed as to turn with two or three grains, when loaded with their greatest weight. They can, when required, be made very delicate and correct, but, except in particular cases, that is not necessary. Another finer instrument, calculated to weigh from half a grain to two or three ounces with considerable accuracy, and turning with about one-hundredth of a grain, should be kept for such laboratory purposes, which require more accuracy. They are intended for common use, and should be substituted as often as possible for the best balance, especially in cases which require the balance in the laboratory, the object being to save the superior instrument from injury by too frequent use, and to preserve it from exposure to the vapors which are constantly evolving in the progress of operations, or from the bottles. The choice instrument should be sufficiently delicate to weigh from 600 to 1000 grains and downwards, indicating distinctly, and with certainty, differences equal to the $\frac{1}{1000}$ or $\frac{2}{1000}$ of a grain. Such an instrument ought never to be kept in the laboratory, but in a separate room adjoining it.

Balances are, therefore, variously constructed, and made of various materials, according to the purposes for which they are intended. The beam is most frequently made of a rod of solid steel, sometimes of two hollow cones, joined at their bases (Troughton's), and in some the beam is a frame in the form of a rhombus. The principal object in all, however, is to combine strength and inflexibility with lightness.

Balances of the most perfect kind are usually furnished with adjustments, by means of which the length of the arms, or the distances of the fulcrum from the points of suspension of the scales, may be equalized, and the line of suspension regulated in regard to the fulcrum, and the centre of gravity of the balance lowered or raised by a movable weight.

Of modern constructions of balances we consider those of Robinson of London as the best. Fig. 6 and 7, Pl. V. represents a drawing of one of his constructions, which we have had in constant employment for a number of years without any perceptible deterioration. Excellent balances of this construction are made in Philadelphia by J. P. Duffey. We subjoin the following description by Capt. Kater. (See *Kater and Lardner's Elements of Mechanic*.)

BALANCE.

The beam of this balance is only ten inches long. It is a frame of bell-metal in the form of a rhombus. The fulcrum is an equilateral triangular prism of steel, one inch in length; but the edge on which the beam vibrates is formed to an angle of 120° , in order to prevent any injury from the weight with which it may be loaded. The chief peculiarity in this balance consists in the knife-edge, which forms the fulcrum bearing upon an agate plane throughout its whole length, whereas in the other balances the whole weight is supported by portions only of the knife-edge, amounting together to one-tenth of an inch. The supports for the scales are knife-edges each six-tenths of an inch long. These are each furnished with two pressing screws, by means of which they may be made parallel to the central knife-edge.

Each end of the beam is sprung obliquely upwards and towards the middle, so as to form a spring through which a pushing screw passes, which serves to vary the distance of the point of suspension from the fulcrum, and, at the same time, by its oblique action, to raise or depress it, so as to furnish a means of bringing the points of suspension and the fulcrum into a right line.

A piece of wire, four inches long, on which a screw is cut, proceeds from the middle of the beam downwards. This is pointed to serve as an index, and a small brass ball moves on the screw, by changing the situation of which the place of the centre of gravity may be varied at pleasure.

The fulcrum, as before remarked, rests upon an agate plane throughout its whole length, and the scale-pans are attached to planes of agate, which rest upon the knife-edges forming the points of support. This method of supporting the scale-pans, we have reason to believe, is due to Mr. Cavendish. Upon the lower half of the pillar, to which the agate plane is fixed, a tube slides up and down by means of a lever which passes to the outside of the case. From the top of this tube, arms proceed obliquely towards the ends of the balance, serving to support a horizontal piece, carrying at each extremity two sets of Ys, one a little above the other. The upper Ys are destined to receive the agate planes to which the scale-pans are attached, and thus to relieve the knife-edges from their pressure; the lower to receive the knife-edges themselves, which form the points of suspension of the pans, consequently these latter Ys, when in action, sustain the whole beam.

When the lever is freed from a notch in which it is lodged, a spring is allowed to act upon the tube we have mentioned, and to elevate it. The upper Ys first meet the agate planes carrying the scale-pans and free them from the knife-edges. The lower Ys then come into action and raise the whole beam, elevating the central knife-edge above the agate plane. This is the usual state of the balance when not in use: when it is to be brought into action, the reverse of what we have described takes place. On pressing down the lever, the central knife-edge first meets the agate plane, and afterwards the two

BALANCE.

agate planes carrying the scale-pans are deposited upon their supporting knife-edges.

A balance of this construction was employed by Captain Kater in adjusting the national standard pound. With a pound troy in each scale, the addition of one-hundredth of a grain caused the index to vary one division, equal to one-tenth of an inch, and Mr. Robinson adjusts these balances so that with one thousand grains in each scale, the index varies perceptibly on the addition of one thousandth of a grain, or of one-millionth part of the weight to be determined.

The following is the method to be pursued in adjusting a balance of this description:

1. To bring the points of suspension and the fulcrum into a right line.

Make the vibrations of the balance very slow by moving the weight which influences the centre of gravity, and bring the beam into a horizontal position, by means of small bits of paper thrown into the scales. Then load the scales with nearly the greatest weight the beam is fitted to carry. If the vibrations are performed in the same time as before, no further adjustment is necessary; but if the beam vibrates quicker, or if it oversets, cause it to vibrate in the same time as at first, by moving the adjusting weight, and note the distance through which the weight has passed. Move the weight then in the contrary direction through double this distance, and then produce the former slow motion by means of the screw acting vertically on the points of suspension. Repeat this operation until the adjustment is perfect.

2. To make the arms of the beam of an equal length.

Put weights in the scales as before; bring the beam as nearly as possible to a horizontal position, and note the division at which the index stands; unhook the scales, and transfer them with their weights to the other ends of the beam, when, if the index points to the same division, the arms are of an equal length; but if not, bring the index to the division which had been noted, by placing small weights in one or the other scale. Take away half these weights, and bring the index again to the observed division by the adjusting screw, which acts horizontally on the points of support. If the scale-pans are known to be of the same weight, it will not be necessary to change the scales, but merely to transfer the weights from one scale-pan to the other.

Delicate balances are always enclosed in a glass case, and are so fixed in them as to admit of their use without removal. The case should open by doors both in front and on the sides, and should always be closed perfectly when not in use. It ought also never to be neglected to keep an open vessel containing dry carbonate of potassa (pearlash) inside the case for the absorption of moisture and other injurious vapors. It is also necessary, for the preservation of the balance, to clean it at least twice a year, by rubbing first with a rag slightly greased with a mixture of sweet olive and a little linseed oil, and afterwards wiping it off with a perfectly clean piece of linen. Special care should be taken never to touch with the fingers

the steel edges or the planes on which they rest.

Those balances, the beams of which are made of a straight piece of steel, answer well where the utmost accuracy is not required, or where only small quantities are to be weighed, but with larger loads they are apt to bend, and thus to give a less delicate result. They possess, however, the great convenience that the beam may be divided into decimal parts, and the last decimal weights ascertained by the next higher decimal weight, made of wire and bent into a hook, so as to slide forward and backward on the upper edge of the beam.

A good balance should always have the middle knife-edge resting wholly or partly on a perfect plane, with some contrivance for elevating the beam, and freeing the knife-edge from its support, both for the purpose of preventing the edge from becoming dull when not used and of stopping the oscillations of the beam while weighing. If the fulcrum rest in a curve, the results are more apt to become uncertain. The same is the case in regard to the suspension of the pans, and more so where these are suspended by hooks or curved edges. In the latter case the pans rest merely in a single point, which is apt to change slightly by unavoidable motions of the pans, and thus produce a very sensible variation in the results, even in balances, which otherwise possess great delicacy. In fine assaying balances, the edges supporting the pans are sometimes curved, forming part of a circle made of agate or some other hard mineral, by drilling and then cutting it into segments, using one part for supporting the edge and the other as a hook for the suspension of the scale on it.

In many cases it will be found convenient to have two pans, one above the other, at least on that side where the weights usually are placed, the upper one being destined for the reception of counterpoises.

Use of the Balance. In the foregoing it has been shown that when the arms of the balance are equal, equal weights in the different pans will produce no change in its horizontality; vice versa, if two bodies placed in the pans produce no change in the horizontality of the beam, we conclude that their weight is equal. Having, therefore, in the first place, ascertained that the balance is in order, as far as regards its perfect equilibrium, freedom of vibration, and delicacy, and that its arms are of the same length (see below), it only becomes necessary to place the body, the weight of which we wish to ascertain in one scale, add weights (see *WEIGHT*) in the other till equilibrium be again restored. The weight of the body is then directly indicated by the weights in the opposite scale. Should the arms of the scale be not exactly of the same length, the weighing may still be performed in the same manner for analysis without injury to the results, if the precaution be observed always to weigh the substance and its ingredients in the same scale, and the weights in the other, since then the same proportion will be preserved in all the weighings between the weights and the weighed bodies, and the relative proportion between these remain perfectly correct.

But if the exact *absolute weight* of a body be required, as, for instance, a certain weight of water or mercury be desired as a measure, or for the comparison of standard weights, it is necessary that the arms should be exactly of the same length, and even then it is better in all delicate scientific operations, where the utmost accuracy is required, not to rely on adjustments at all, but to perform the weighing, or the comparison between standard weights by one and the same arm. For such purposes we subjoin the following directions for the use of one of Robinson's or any other similarly constructed balance.

Having levelled the case which contains the balance, and thrown the beam out of action, place a weight in each scale-pan nearly equal to the weight which is to be determined. Lower the beam very gently till it is in action, and by means of the adjustment for raising or lowering the centre of gravity, cause the beam to vibrate very slowly. Remove these weights, and place the substance, the weight of which is to be determined, in one of the scale-pans; carefully counterpoise it by means of any convenient substances put into the other scale-pan, and observe the division at which the index stands; remove the body, the weight of which is to be ascertained, and substitute standard weights for it so as to bring the index to the same division as before. These weights will be equal to the weight of the body.

If it be required to compare two weights together, which are intended to be equal, and to ascertain their difference, if any, the method of proceeding will be nearly the same. The standard weight is to be carefully counterpoised, and the division at which the index stands, noted. And now it will be convenient to add in either of the scales some small weight, such as one or two-hundredths of a grain, and mark the number of divisions passed over in consequence by the index, by which the value of one division of the scale will be known. This should be repeated a few times, and the mean taken for greater certainty.

Having noted the division at which the index rests, the standard weight is to be removed, and the weight which is to be compared with it substituted for it. The index is then again to be noted, and the difference between this and the former indication will give the difference between the weights in parts of a grain.

If the balance is adjusted so as to be very sensible, it will be long before it comes to a state of rest. It may, therefore, sometimes be advisable to take the mean of the extent of the vibrations of the index as the point where it would rest, and this may be repeated several times for greater accuracy. It must, however, be remembered, that it is not safe to do this when the extent of the vibrations is beyond one or two divisions of the scale; but with this limitation it is, perhaps, as good a method as can be pursued.

It will be seen that, in order to ascertain a body's weight by this method, it requires to restore the equilibrium of the balance twice, for which reason it has been called *double weighing*. This may, however, be avoided, in repetition of the same experiments, by placing

on the opposite pan a counterpoise heavier than the body to be weighed, and determining, with accuracy, the weight which is required to restore the equilibrium. It is then only necessary in the subsequent weighings to replace this weight by the body, and restore the equilibrium by the addition of smaller weights, which, subtracted from the first, give the true weight of the body.

It is obvious that the excellence of the balance would, even with all possible care in weighing, be of little use, unless the weights employed were equally to be depended on. For their adjustment, we refer to article **WEIGHTS**. The weights should never be touched by the hand, by which they would become tarnished. For the larger weights a wooden fork or tongs should be employed, and for the smaller, a pair of forceps made of brass or copper, having sufficient elasticity to open on their being released from pressure, and yet not opposing a resistance sufficient to interfere with that delicacy of touch which is desirable in such operations.

In estimating or counting the weights in the pan errors are often committed, which sometimes ruin the result of much labor. The weights should therefore always after attained equilibrium be spread out in the pan, or on a piece of paper, according to their denomination, the amount noted down, and then compared with the vacancies in the box, wherein the weights are kept and where every weight should have its own compartment with the mark of its value attached to it.

Although when the balance is in perfect order, it is indifferent which pan receives the substance and which the weights, it is best always to use the same pan for the same purpose. Attention to this custom, as stated before, is also, in most chemical operations, where the relative and not the absolute weights are of importance, a correction for any inequality in the length of the arms.

The substances which are to be weighed ought never to be laid at once on the pan, but on some interposed substance, as a piece of glazed letter-paper, &c., counterpoising it by another of the same size, or a counterpoised watch-glass or crucible (see under **ANALYSIS**, § 4. *Weighing*). Counterpoises for the latter may be conveniently made of small glass tubes or vials, closed by a good cork, and filled with shot or sheet-lead. To avoid mistakes, they ought to be labelled.

In weighing substances that have been heated, great attention should be paid not to weigh them or place them on the balance before they have become cold, otherwise the ascending current of hot air which issues from it will elevate the pan and cause considerable error. If the substance be apt to attract moisture during the process of cooling, the latter must be performed in a receiver over sulphuric acid. Pulverulent substances are especially apt to attract moisture, and should, therefore, in most cases be first heated for its expulsion, and left to cool in the above manner.

During delicate weighings the balance should be protected against any disturbing influence from drafts of air, by keeping the

doors of the case closed, and also be screened against the sun's rays, or other radiated or reflected heat.

Vessels with round bottoms are supported on the pans by counterpoised rings, or stands, made of paper, pasteboard, cork, or tin. (See *Fig. 9*, p. 169, under **ANALYSIS**.) Tubes and other irregular apparatus may be kept upright or suspended by thin wire bent into a hook and attached to the piece of wire to which the suspending strings of the pan are fixed.

BALLOON. *Chem. Fr. Ballon.* Glass vessels of a spherical form, with a short neck. They are either used as receivers (see this) in distillation, from which they then only differ by their larger size and shorter neck, or for the collection and weighing of gases, in which latter case their neck is narrower, and furnished with a cock and a screw to connect it air-tight with the air-pump and other apparatus.

BALLOON. *Tech.* A machine which, by being specifically lighter than common air, will rise into the atmosphere with greater or less ascensional force.

The principle by which a balloon rises in the atmosphere is exactly the same as that which causes the ascent of a cork from the bottom of a vessel filled with water. The weight of the volume of air which it displaces must exceed the weight of the balloon with all its appurtenances. Balloons are generally of a spherical form, made of some light fabric, and filled with a gas specifically lighter than common air. The best material of which they at present are made is thin silk, varnished with caoutchouc (Indian rubber). The quantity of this material required to cover a globe one foot in diameter, weighs about $\frac{1}{25}$ of a pound avoirdupois. For globes of greater size, the quantity required will increase with the square of the diameter. Hence the covering of a balloon 12 feet in diameter would weigh about 7 lbs., and one of 24 feet diameter 28 pounds.

The gases with which balloons are filled, in order to render them specifically lighter than the surrounding air, are either common atmospheric air kept rarified in the balloon by a fire beneath an opening in its lower part, or hydrogen or common illuminating gas. If the latter two be employed, the balloon must of course be closed to prevent the gas from escaping. Hydrogen gas is much the lightest for such purposes. Obtained in the usual way, by dissolving iron filings in dilute sulphuric acid, it may be assumed (making every allowance for imperfect preparation) to be about six times lighter than atmospheric air, a globe of which, one foot in diameter, at the level of the sea, and under the ordinary pressure, weighs about $\frac{1}{25}$ of a pound avoirdupois. But the comparative cheapness and facility with which balloons may now be filled by common coal or illuminating gas, have of late caused the latter to be generally employed for balloon ascension, notwithstanding its greater specific gravity; it only being from $\frac{1}{2}$ to a $\frac{1}{3}$ lighter than common atmospheric air.

To the balloon is generally attached the *car* or *basket*, suspended by a net-work, which extends over the balloon and which supports

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the æronaut and his ballast. By throwing the latter overboard, the balloon may be made lighter, and thus acquire new ascending force, while, by allowing the gas to escape through a valve, usually placed at the top of the balloon, with a string attached to it, the balloon may be made to descend at pleasure.

To the two brothers Montgolfier, proprietors of a paper manufactory at Annonay in France, is due the honour of first having prepared and sent up a balloon into the air in June, 1783. The balloon was prepared of linen cloth made to ascend by a fire kindled under it, and fed with bundles of chopped straw. The first balloon filled with hydrogen was shortly afterwards sent up by Charles, a lecturer at Paris. Pilatre de Rosier and Marquis d'Arlandes were the first who ventured to ascend in a balloon. The former afterwards lost his life in an attempt to cross the Channel in a balloon, which took fire immediately on its ascent.

There is no doubt, both from theoretical considerations and from late experiments, that locomotion may be imparted by machinery to balloons; what at present is mostly desired for their employment for useful purposes is a material of sufficient lightness, strength, and impenetrability to gases. A balloon has, besides, the advantage of being able to avail itself of the different currents of air which are known to exist at different heights.

BALSAMS. This term was formerly applied to all liquid vegetable resins as well as to many pharmaceutical preparations. But, to avoid confusion, the French chemists confine the term balsam to vegetable substances composed of benzoic acid with more or less volatile oil. But as this would exclude copaiva and some other substances, popularly called balsams, most of the German chemists retain the old acceptance of the term, and divide balsams into those which do not and those which do contain this acid. To the former, which also are called oleo-resins, liquid resins, terebinthinates belong: the different terpenes (including Canada-balsam), copaiva, and opobalsamum or Mecca-balsam (which see), they are semi-liquid resinous or glutinous juices, which flow spontaneously or by incisions from various vegetables, especially those belonging to the orders Coniferae, Terebinthaceae, and Leguminosae. They have a hot and acrid taste, and a strong odor, which, in some, is very fragrant, in others less agreeable, but peculiar. They consist of a volatile oil and resin. Their odor, their semi-liquidity, and most of their medicinal activity are owing to the volatile oil which they contain, and which may be procured from them by distillation, and which volatilizes by exposure to air, whereby they become hard. From the next, or true balsams, they are distinguished by not yielding benzoic acid. Those balsams which contain benzoic acid or balsams, more properly so called, are solid, soft, or liquid substances, according to the quantity of volatile oil which they contain; they have an aromatic, usually agreeable odor, and a warm acrid taste. They dissolve in alcohol, and the solution, when mixed with water, becomes milky, owing to the precipitation of resin. By sublimation, as well as by other

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methods, they yield benzoic acid. They owe their principal medicinal activity to the contained benzoic acid. They are obtained principally from the orders Styracae, Leguminosae, and Balsamaceae. To this class belong Benzoin, Styra, Tolu, Peruvian balsam, and Liquidambar (see these). The natural production, called Chinese Varnish, belongs also to this class.

BALSAM OF SULPHUR. *Pharm.* A solution of sulphur in oil by boiling. Forms a dark-reddish brown viscid substance of an extremely unpleasant odor.

BALDWIN'S PHOSPHORUS. Ignited nitrate of lime, so called, on account of the faint phosphorescence which it emits in the dark.

BAMLITE. *Min.* H. = 6. + G. = 2984. Radiated, grayish white, translucent, with uneven, splintery fracture.

Analysis by Erdman:—

		Oxygen.	
Silica.....	56.90	= 29.56	3
Alumina.....	40.73	} = 19.34	2
Peroxide of iron....	1.04		
Lime.....	1.04	—	—
Fluorine.....	trace	—	—
	99.71	—	—

Its form. is $2\text{Al}_2\text{O}_3, 3\text{SiO}_2$, or $\text{Al}_2\text{O}_3, 3\text{SiO}_2 + \text{Al}_2\text{O}_3$; the former of which is $\frac{2}{3}$ silicate of alumina, the latter neutral silicate of alumina + alumina. It occurs at Bamle in Norway, and was described and analyzed by Erdmann. (*Berz. Jahresb.* xxii. 196.)

BARBERRY. The root of this plant (*Berberis vulgaris*) contains a yellow coloring matter, Berberin, and is employed in dyeing or staining Morocco leather. The coloring matter is found in the whole of the root of the plant, but in the stem only around the pith and near the bark. The great bulk of the woody fibre contains no color. The finest color is found in the largest stems. The root contains about 17.6 per cent. of the yellow color (see BERBERIN), and besides a brown coloring matter contained in the epidermis and precipitable by acetate of lead.

BARIUM. *Chem.* The metallic base of baryta, one of the earthy alkalies, occurring in heavyspar and several other minerals, and called baryta, from βαρύς, heavy, on account of the density of its compounds.

I. BARIUM AND ITS METALLOIDAL COMPOUNDS.
Barium. *Equiv. Ba.* = 68.66, or 856.88 (O = 100).

Prep. Carbonate of baryta is formed into a paste with water, and put on a platinum dish communicating with the positive wire of a strong galvanic battery of at least 100 pair, on account of the strong intensity which it requires to decompose it. Mercury is placed in a hollow made in the baryta and connected with the negative wire. An amalgam is then formed of mercury and barium. This amalgam is distilled in a bent tube filled with hydrogen. It is, however, difficult to free it entirely from the mercury, for, if the heat be raised to redness, the barium reduces the glass. It may likewise be procured by passing potassium in vapor over caustic baryta heated to redness in an

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iron tube, separating the reduced barium from the formed suboxide of potassium by means of mercury, and freeing it from the latter by distillation.

Prop. Barium is a white metal like silver, heavier than water and sulphuric acid, in which it sinks. It fuses below a red heat, and when exposed to the air becomes covered with a crust of baryta. In water it oxidizes rapidly, disengaging hydrogen and being converted into baryta. It is slightly malleable.

Barium combines with oxygen in two proportions, forming two oxides, baryta and the peroxide of barium.

1. *Baryta.* Syn. Oxide of Barium, Protoxide of Barium, Barytes. *Ger.* Baryterde, Schwererde, discovered 1774 by Scheele. Occurs in several minerals, of which the most abundant are sulphate of baryta, or heavy spar, and carbonate of baryta and witherite.

Prop. Pure baryta is obtained in its anhydrous state by calcining nitrate of baryta at a bright red heat in a porcelain retort, or in a well-covered crucible of porcelain or silver, but not of platinum. If the calcination be not carried sufficiently far, a combination remains of baryta and nitrous oxide, which has been mistaken for peroxide of barium. It may also be obtained by the calcination of iodate of baryta in a porcelain retort, which is more easily decomposed, and does not fuse or swell up. The iodine comes off with oxygen, and may be recovered. It may also be obtained from carbonate of baryta by mixing 100 parts of the latter with 6 to 10 pts. finely pulverized charcoal, forming it into balls with a solution of tragacanth and exposing these, packed in charcoal-powder in a covered crucible in a forge to a strong heat for nearly an hour. Thus obtained, it always contains some carbon, and sometimes some undecomposed carbonate of baryta.

Prop. It forms a gray powder of specific gravity of about 4; is only fusible by the hydrogen blowpipe. When heated to redness in a porcelain tube and oxygen passed over it, it absorbs that gas with avidity and becomes peroxide of barium. Moistened with water, it evolves much heat, and slackens to a white powder; with more water, it becomes hard and crystalline.

Hydrate of Baryta. If anhydrous baryta be treated with water, it combines with it as stated, and dissolves in a greater quantity of boiling water. The solution is called *barytic water*, and is strongly caustic, although less so than po-

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tassa or soda. Exposed to the air, it absorbs carbonic acid, and becomes turbid from the precipitation of carbonate of baryta. Evaporated in a retort to about $\frac{2}{3}$ its bulk, it deposits, on cooling, the hydrate in crystals. By further evaporation and cooling more crystals are obtained. Another method of obtaining them is to treat a boiling solution of sulphuret of barium (see this) in a flask with black oxide of copper, adding it in successive small portions, till a drop of the liquid does no longer blacken a solution of lead, but precipitates it entirely white; the liquid contains then only hydrate of baryta in solution, which is separated by filtration and evaporated in the same way to crystallization. The crystals are transparent, 4-sided, or flat 6-sided, prisms, terminated by 4 planes; soluble in 3 pts. of boiling water and in 20 pts. of water at 66°. They contain 9 atoms of water; by a moderate heat, they melt in their water of crystallization and lose 7 atoms, and by a stronger heat one more, or about half their own weight of water. The hydrate then remains as a white powder, retaining one atom of water, which cannot be expelled by heat, but a little below redness it fuses and congeals, on cooling, to a crystalline mass, resembling somewhat fused hydrate of potassa. The hydrate of baryta is also soluble in alcohol, but it requires 150—160 pts. of this liquid at its boiling point for solution.

Heated with carbon in excess, hydrated baryta yields carbonate of baryta and free hydrogen. Heated in carbonic oxide, it yields carbonic acid and hydrogen. Baryta is remarkable for its strong affinity for sulphuric acid, in which point it surpasses all other bases, forming with it a compound, insoluble both in water and dilute acids, and which, therefore, is used for their mutual detection and quantitative estimation.

Composition of Anhydrous Baryta.

	H=1.	O=100.	In 100 pts.
Ba.....	68.6	856.88	89.55
O.....	8	100	10.45
BaO	76.6	956.88	100

Of fused Hydrate of Baryta.

		In 100 pts.
BaO	76.6	89.5
HO	9	10.5
BaO, HO	85.6	100

Of Crystallized Baryta.

			Smith.	R. Phillips.	Noad.	H. Rose.
BaO	76.6	48.61	48.21	47.28	46.94	46.66
9 HO	81	51.39	51.79	52.72	53.06	53.34
BaO, 9 HO	157.6	100	100	100	100	100

The analysis of Rose and Noad lead to a formula with 10 eq. water.

Uses. Baryta is a valuable test in analytical chemistry, and its soluble salts are used more especially for the precipitation and estimation of sulphuric acid. In the arts and manufac-

tures sulphate of baryta is employed as an addition to white lead, but it possesses less body than the carbonate of lead. It is also used as an addition in the manufacture of some varieties of Wedgewood ware and glass.

2. *Peroxide of Barium.* Syn. Hyperoxide of

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Barium, Deutoxide of Barium. *Ger.* Super-oxyd, discovered by Thenard. Formed by combustion of barium in oxygen.

Prepared by passing oxygen over anhydrous baryta heated to redness in a porcelain tube, whereby it is absorbed so completely, that when oxygen appears at the other end of the tube most of the baryta is already converted into the peroxide. The oxygen must be freed previously from its carbonic acid and water, which would decompose the peroxide, by passing it over caustic potassa.

Prop. Peroxide of barium is of a grayish color. Mixed with water in the state of a fine powder, it is converted into a hydrate without generating heat, and forms a perfectly white powder. The hydrate may also be prepared by heating anhydrous baryta in a platinum crucible to a low red heat, and then gradually adding chlorate of potassa in the proportion of about 1 part of the latter to 4 parts of the former. The remaining mass, which is a mixture of chloride of potassium and peroxide of barium, is treated with cold water, which dissolves the chloride of potassium and leaves the peroxide of barium in the state of hydrate. It is then dried in the open air without the aid of heat. According to Saussure, this hydrate is obtained in crystals by exposing a small quantity of barytic water in a large bottle to atmospheric air freed from its carbonic acid. Its principal use is for the preparation of the peroxide of hydrogen. The anhydrous peroxide may be heated to redness without decomposition; at a higher temperature and in an open vessel it loses part of its oxygen. The hydrate, on the contrary, is decomposed by boiling water with the evolution of oxygen; nor can it be dried by heat or in vacuo without suffering decomposition. From the facility with which it is decomposed it has an alkaline taste and exhibits an alkaline reaction.

Comp. Peroxide of barium consists of 1 eq. barium and 2 eq. of oxygen, BaO_2 . Its equiv. is 84.61, or 1056.88 ($\text{O} = 100$). It contains in 100 pts. 81.08 barium + 18.92 oxygen. The hydrate of the peroxide contains, according to Liebig and Wöhler, 6 eq. water, $\text{BaO}_2 + 6\text{HO}$.

1. *Sulphuret of Barium.* *Ger.* Schwefelbarium. It may be obtained by passing sulphuretted hydrogen over pure baryta heated to redness in a glass or porcelain tube, or by igniting sulphate of baryta with finely pulverized charcoal. This last method is generally employed for the preparation of sulphuret of barium, in order to obtain baryta or other salts of baryta from it. Eight parts of finely pulverized sulphate of baryta are mixed intimately with 1 pt. of finely pulverized charcoal and 2 pts. resin or flour, and the mixture exposed in a well-covered Hessian crucible to a white heat for $\frac{3}{4}$ of an hour, raising the temperature slowly. The carbon then combines with the oxygen of the sulphur and the barium to carbonic acid gas, which escapes, while sulphuret of barium remains mixed with carbon. The residuary mass is treated with boiling water, and the solution filtered while yet hot. On cooling, it then deposits crystals of the protosulphuret of barium, but with water of crystallization.

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Comp. The protosulphuret of barium consists of 1 eq. sulphur and 1 eq. barium, BaS . Its atom. weight is 84.6, or 1058.05 ($\text{O} = 100$); it contains 80.99 per cent. of barium + 19.01 per cent. sulphur.

According to Liebig, the sulphuret of barium may be obtained on a larger scale in the following way. Five parts finely pulverized sulphate of baryta are mixed with 1 pt. powdered charcoal and so much paste of flour as to allow the mass to be formed into cylinders, which are dried. These cylinders are placed on a deep layer of coal in a furnace; the draft of which may be shut off and piled with interstratified layers of charcoal. After the whole has been fired completely, the draft is closed so as to allow the fire to go out slowly and the furnace to become cold. After the lapse of 6 hours the operation is complete, since the mixture only requires a low but long-continued ignition. They then consist of a mixture of baryta and bisulphuret of barium, which may be separated by boiling water, which leaves the greater part of the baryta behind the portion that dissolves, separating in crystals on cooling, while the sulphuret remains in solution.

Rose has lately shown that by dissolving protosulphuret of barium in water, a portion is always converted into hydrate of baryta and sulphhydrate of barium ($2\text{BaS} + 2\text{HO} = (\text{BaO} + \text{HO}) + (\text{BaS} + \text{HS})$).

A solution of sulphuret of barium kept several years, deposited crystals of baryta, then crystalline scales *c*, lastly 6-sided pyramids *b*, and by concentrating the solution in a retort, a white powder deposited of hydrated sulphuret of barium, *a*. According to Rose, the white powder, *a*, has the formula, $\text{BaS}, 6\text{HO}$; the crystals, *b*, are $\text{BaO}, 10\text{HO} + 3(\text{BaS}, 6\text{HO})$; and the crystalline scales about $4(\text{BaO}, 10\text{HO}) + 3(\text{BaS}, 6\text{HO})$. (*H. Rose.*)

2. *Higher Sulphurets of Barium.* These have not been much investigated. A mixture of the tersulphuret and sulphate of baryta is obtained by fusing 8 pts. of pure baryta with 6 pts. of sulphur; from which water will dissolve the tersulphuret, leaving the sulphate of baryta behind ($4\text{BaO} + 10\text{S} = 3\text{BaS}_3 + \text{BaO}, \text{SO}_3$). A solution of the pentasulphuret is obtained by boiling a solution of the protosulphuret with sulphur. The same, but mixed with hyposulphite of baryta, is obtained by boiling pure baryta with sulphur. The pentasulphuret of barium is very soluble in water and alcohol. By evaporation of its solution in vacuo, it forms a mass of a pale yellow color. It consists of 1 at. of barium with 5 at. of sulphur, $\text{Ba} + \text{S}_5$, and contains 54 per cent. of sulphur.

Phosphuret of Barium. Obtained by throwing phosphorus on anhydrous baryta, heated to redness in a long-necked glass flask. Phosphuret of barium and phosphate of baryta are formed. The mass fuses and exhibits, on cooling, a brown color and metallic lustre. Too much heat decomposes again the phosphuret, volatilizing the phosphorus, and leaving the baryta behind. With water, the phosphuret of barium is decomposed, forming hypophosphite of baryta with the generation of whosphuretted hydrogen.

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II. SALTS OF BARIUM.

The salts of barium have a disagreeable, bitter, saline taste. The presence of baryta in them is recognised by their giving, when dissolved in water or a dilute acid, with sulphuric acid or a sulphate, a white precipitate, insoluble in water and chlorohydric and nitric acids. The soluble salts of baryta are not precipitated by pure ammonia or sulphhydrate of ammonium, nor by sulphuretted hydrogen. The alkaline carbonates cause a white precipitate of carbonate of baryta. The different salts of baryta are generally prepared by adding dilute acids to a solution of the sulphuret of barium, by which sulphuretted hydrogen is given off.

HALOID SALTS.

Chloride of Barium. Syn. Muriate of Barytes. Ger. Chlorbarium, Salzsäure Baryterde.

Prep. By dissolving carbonate of baryta in dilute chlorohydric acid, or by adding the same acid to a solution of sulphuret of barium (see this) till it assumes an acid reaction, filtering, evaporating, and igniting it strongly in an open fire, by which foreign matters, such as salts of iron are rendered insoluble. The mass is then redissolved in water and evaporated to crystallization.

Prop. Chloride of barium is obtained in flat rhomboidal tables, bevelled at the edges, containing water of crystallization. It does not change by exposure to the air. By ignition it loses its water of crystallization, but is not decomposed. 100 pts. water dissolve 32.62 pts. of the anhydrous salt at 32°, and for every degree above this temperature 1.506 more. 100 pts. of water dissolve 43.5 pts. of the crystallized salt at 59°, and at the boiling point of the saturated solution, which occurs at 220.9°, it dissolves 78 pts. If the solution contain chlorohydric acid, it is less soluble, and even insoluble in a concentrated acid, so that it may be precipitated in considerable quantity from its solution in water by the addition of this acid. It is soluble in dilute alcohol, but anhydrous alcohol dissolves only $\frac{1}{400}$ of its own weight.

Comp. Chloride of barium consists of 1 eq. of each of its elements, Ba + Cl. Its atom. weight is 104.13, or 1299.53 (O. = 100); it contains, in 100 pts., 65.94 barium + 34.06 chlorine. The crystallized = BaCl + 2 HO, or 14.75 per cent. water.

Eromide of Barium. Prepared by dissolving carbonate of baryta in bromohydric acid, or by adding the latter to a solution of sulphuret of barium till it becomes saturated, filtering and evaporating the solution. Is very soluble in water, and crystallizes by evaporation and cooling in rhombic tables, resembling those of the chloride, with which it is isomorphous, and analogous in composition, containing 2 equiv. water, or in fine needles, or in small warty crystals. It is soluble in anhydrous alcohol, by which it may be separated from the chloride. Formula of the anhydrous, BaBr, containing 53.33 per cent. bromine; of the crystals, BaBr, 2 HO, containing 11.32 per cent. water. (Rammelsberg.)

Iodide of Barium. BaI. May be formed by

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heating baryta in iodohydric acid gas, the combination taking place with combustion.

Prepared most conveniently by adding a saturated alcoholic solution of iodine to a solution of protosulphuret of barium as long as any sulphur separates, filtering the solution and evaporating it quickly almost to dryness, redissolving it in a small portion of water and boiling it down in a flask to dryness. It is very soluble in water, and may be obtained in small deliquescent crystals, soluble in alcohol, very soluble in water. Exposed to the atmosphere, it loses a portion of its iodine, with the formation of carbonate of baryta, after which the iodine of barium dissolves with a brown color. The same change is effected more rapidly by ignition in the open air. In closed vessels it suffers no change. The anhydrous salt = BaI with 64.75 per cent. iodine (according to O. Henry, 64.83); the fine needles contain water.

Fluoride of Barium. BaF. *Prep.* by digesting freshly precipitated carbonate of baryta with fluohydric acid in excess. Carbonic acid gas is expelled and fluoride of barium remains as a white powder, while only a small portion remains dissolved in the excess of acid. It is soluble to a certain degree in the wash-water, which deposits it on evaporation as a finely granular crust. It is not decomposed by ignition; soluble in nitric and chlorohydric acids.

Fluoride of barium combines with chloride of barium to a double haloid salt, which is obtained by precipitating fluoride of potassium or sodium with chloride of barium or by dissolving fluoride of barium in chlorohydric acid and precipitating by ammonia. Is much more soluble in water than the simple fluoride of barium, and deposits, on evaporation, in granular crystals. By long washing with water it is partially decomposed, the remaining salt becoming richer in fluoride of barium. The barium is, in this salt, equally divided between the chlorine and the fluorine, BaCl + BaF.

Borofluoride of Barium. BaF, BF₃ + 2 HO. Syn. Fluoroborate of Baryta. *Prep.* by dissolving carbonate of baryta in dilute borofluohydric acid as long as it leaves no residue. If more carbonate be added, the salt is decomposed into fluoride of barium and boracic acid. By evaporation, some boracic acid generally separates at first, contained in the borofluohydric acid, and after the solution has obtained the sirupy consistence, the salt crystallizes, on cooling, in long needles, and by continued evaporation in a warm place in flat rectangular prisms. It has an acid reaction, but not acid taste. Effloresces at 104° and becomes opaque; deliquesces in damp air; dissolves in water without decomposition; is decomposed by alcohol, which dissolves an acid salt and leaves a white residue. Decomposed by ignition into borofluohydric acid, fluoride of boron, and leaves behind fluoride of barium. The crystallized salt contains 10.34 per cent. of water.

Silicofluoride of Barium. 3 BaF + 2 SiF₃. Obtained by mixing a solution of chloride of barium with silicofluohydric acid. The precipitate appears, after some time, in the form of small microscopic crystals. The baryta is precipitated almost completely, a very minute quantity only remaining, dissolved in the free

chlorohydric acid, by which its solubility is but slightly increased. It contains no water of crystallization; is easily decomposed by ignition into fluoride of silicon and fluoride of barium, which remains behind.

OXYSALTS.

1. *Sulphate of Baryta.* $\text{BaO} + \text{SO}_3$. Occurs native as a mineral, both compact and in crystals (see **HEAVY-SPAR**). Artificially, it is generally obtained as a white powder, perfectly insoluble in water and free acid. Dissolves in concentrated sulphuric acid, by boiling, and deposits, on cooling, in needle-shaped crystals. By dilution with water, it is completely precipitated; fuses, by strong ignition, into a white enamel; is reduced, by ignition with charcoal, to sulphuret of barium; is only partially decomposed by the alkaline carbonates, either by ignition or by boiling with their concentrated solutions. In analytical chemistry, it often happens in the precipitation of baryta by sulphuric acid, that the sulphate of baryta remains suspended as an extremely fine powder, which passes through the filter. This is most apt to happen at a certain concentration, and when the solution is neutral, but does not take place when it is previously made acid, or when it is dilute or concentrated. The presence of a salt of soda seems to favor its separation in this state, which, when once present, is very difficult to remedy.

Composition. The sulphate of baryta consists of 1 eq. sulphuric acid, with 1 eq. baryta. Its atomic weight is 119.56, or 1458.05 ($\text{O} = 100$); and it contains, in 100 pts., 65.63 baryta and 34.37 sulphuric acid.

2. *Hyposulphate of Baryta.* $\text{BaO} + \text{S}_2\text{O}_5$. Obtained by precipitating a solution of hyposulphite of protoxide of manganese by sulphuret of barium and evaporating the filtered solution to crystallization. By repeated crystallization, the crystals are obtained perfectly pure. By spontaneous evaporation, it crystallizes in oblique 4-sided prisms, with 4-sided pyramids, and containing 19.48 per cent. of 4 eq. water, of which it loses, by exposure to the air, one half, but, by cooling, it is obtained in rectangular 4-sided prisms, which do not change in the air; dissolve in 1 pt. of boiling and in 4.04 pts. water at 64° , and contain 10.79 per cent., or 2 eq. crystal-water. By heat, it decrepitates, gives off water and sulphurous acid, and leaves 70.1 per cent. sulphate of baryta. Formula of the oblique prisms, $\text{BaO}, \text{S}_2\text{O}_5 + 4 \text{HO}$, of the rectangular prisms, $\text{BaO}, \text{S}_2\text{O}_5 + 2 \text{HO}$.

3. *Sulphite of Baryta.* $\text{BaO} + \text{SO}_2$. *Prep.* by suspending carbonate of baryta in water and passing sulphurous acid gas through it, or by precipitating chloride of barium by sulphite of soda. Forms a tasteless and insoluble powder. Dissolves in an excess of sulphurous acid, and deposits, by evaporation, in transparent tetrahedrons, with replaced edges and of considerable hardness.

4. *Hyposulphite of Baryta.* $\text{BaO} + \text{S}_2\text{O}_4$. Obtained by passing sulphurous acid into a solution of sulphuret of barium, or by allowing a solution of the latter to oxidize slowly by exposure to the atmosphere. It crystallizes in trans-

parent needles, containing 6.73 per cent. water. Form., $\text{BaO}, \text{S}_2\text{O}_4 + \text{HO}$.

1. *Nitrate of Baryta.* $\text{BaO} + \text{NO}_3$. *Prepared* by adding sufficiently diluted nitric acid, during continued stirring, to a solution of sulphuret of barium. Water is decomposed, the barium taking the oxygen and combining with the nitric acid, while the hydrogen combines with the sulphur, forming sulphuretted hydrogen, which escapes. If the nitric acid be too concentrated, it is apt to oxidize a portion of the sulphuret of barium into sulphate. The hot filtered solution is then evaporated to crystallization. It may also be obtained by dissolving carbonate of baryta in dilute nitric acid.

Prop. It crystallizes in fine, transparent octahedra, without crystal water, but decrepitating violently by heating, causing the crystals to fall to a white powder. It does not change in the air. 100 pts. of water dissolve 5 pts. of this salt at 32° , 8 pts. at 59° , 17 pts. at 120° , 29.6 pts. at 133° . The saturated solution contains, at its boiling point (214°), 35.9 pts. of the salt. Is much less soluble in a solution containing free nitric acid, so that the addition of this latter to a saturated solution will cause the precipitation of a portion of the salt; and in a stronger acid, it is so insoluble as to prevent the solution of carbonate of baryta. It is insoluble in alcohol. By ignition in a porcelain retort, it yields pure baryta; ignited in a platinum crucible, it becomes contaminated with oxide of platinum. Its equiv. is 130.93, or 1633.92 ($\text{O} = 100$), and it contains 58.56 per cent. baryta and 41.44 nitric acid.

Use. A mixture of sulphuret of antimony, sulphur, chlorate of potassa, and nitrate of baryta, in which the last constitutes less than $\frac{1}{2}$ of the whole mixture, is employed as a green fire in fire-works, without force.

2. *Nitrite of Baryta.* Syn. Hyponitrite of Baryta. *Ger.* Salpetrigsaure Baryterde. *Prepared* by gentle ignition of nitrate of baryta, dissolving the mass in water, evaporating to dryness, redissolving, filtering it from the formed carbonate of baryta, and evaporating to crystallization. The crystals do not change in the air. Form., $\text{BaO}, \text{NO}_2 + \text{HO}$.

1. *Phosphate of Baryta.* *Ger.* Phosphorsaure Baryterde. a. *Neutral.* 2 $\text{BaO} + \text{PO}_5$. Obtained by adding gradually a solution of common phosphate of soda to a solution of chloride of barium, the latter remaining in excess. If, on the contrary, the chloride of barium be added to the phosphate of soda, the latter becomes acid, while a basic salt precipitates. The neutral salt requires 20.500 pts. of water for its solution. It dissolves easily in dilute chlorohydric and nitric acids, by which it is converted into an acid salt of easy solubility. Stronger acids dissolve it with greater difficulty on account of the insolubility of the formed chloride, or nitrate, in these acids. It is but sparingly soluble in acetic acid, of which it requires 400 pts. of spec. grav. of 1.032. Sulphuric acid liberates the phosphoric acid completely, forming insoluble sulphate of baryta. It consists of 2 eq. of baryta and 1 eq. of phosphoric acid, and contains, in 100 pts., 68.20 baryta and 31.80 phosphoric acid.

b. *Biphosphate of Baryta.* $\text{BaO} + \text{PO}_5$. Ob-

tained by digesting a solution of phosphoric acid with neutral phosphate of baryta. The latter dissolves and, by evaporation, the salt deposits in crystals, and may be dried on blotting-paper. The remaining mother-liquid is almost free from baryta. This salt does not change in the air, but water decomposes it into phosphoric acid, retaining a small portion of baryta and neutral phosphate, which remains. At a higher temperature it fuses, froths up, and leaves a porous mass resembling burnt alum. The crystal contains 11 per cent. of water of crystallization. Form., $\text{BaO}, \text{PO}_5 + 2 \text{HO}$. In its anhydrous state it consists of 52.75 baryta and 48.25 phosphoric acid.

c. If the saturated solution of phosphate of baryta in phosphoric acid, instead of being left to crystallize, be mixed with alcohol, a white, flocculent precipitate is obtained, which forms a different acid salt containing one and a half times the amount of base as the foregoing, being $3 \text{BaO} + 2 \text{PO}_5$. When washed and dried, it forms a light white powder.

d. Basic phosphate of baryta. $5 \text{BaO} + 2 \text{PO}_5$. Obtained by digesting neutral or acid phosphate of baryta with ammonia. Forms a white powder, which absorbs no oxygen from the atmosphere. Another basic salt, $3 \text{BaO} + \text{PO}_5$, is obtained, according to Graham, by precipitating chloride of barium with basic phosphate of soda.

e. Metaphosphate of Baryta. 1. According to Graham, neutral metaphosphate of baryta is obtained by precipitating a concentrated solution of metaphosphate of soda by chloride of barium in excess. The gelatinous precipitate is washed and dried. Forms a transparent mass, which fuses imperfectly by heat, and dissolves then with difficulty in nitric acid; insoluble in boiling water. By continued boiling, water dissolves common biphosphate of baryta from it.

2. Phosphite of Baryta. a. Neutral. $2 \text{BaO} + \text{PO}_3$. Obtained by Berzelius by adding phosphite of ammonia to chloride of barium. After the lapse of 24 hours, or more, the phosphite of baryta deposits as a crust. In dry air it effloresces. Formula, $2 \text{BaO}, \text{PO}_3 + 2 \text{HO}$, or 7.94 per cent. water of crystallization. By a red heat it is converted into neutral phosphate of baryta.

b. Biphosphite of baryta, $\text{BaO} + \text{PO}_5$, is obtained by dissolving the former in phosphorus acid, and evaporating the solution with a gentle heat. It forms a syrupy mass, which crystallizes with difficulty. A solution of the crystallized salt in water is decomposed by heat into neutral phosphite, which precipitates in crystals, and an acid salt, which remains in solution.

3. Hypophosphite of Baryta. $\text{BaO} + \text{PO}$. Ger. Unterphosphorigsaure Baryterde. Obtained by boiling phosphorus with hydrated baryta, or by digesting phosphuret of barium with water, and filtering the solution. It crystallizes on cooling the hot solution in pearly, flexible prisms, soluble in 3.5 cold and 3 boiling water, insoluble in alcohol; loses 6.28 per cent. water at 212° ; when heated, gives off water, then much self-inflammable, and, lastly, a little not self-

inflammable phosphuretted hydrogen gas, leaving 80.14 per cent. chiefly phosphate of baryta; $2 (\text{BaO}, \text{PO}, 2 \text{HO}) = 2 \text{BaO}, \text{PO}_5 + \text{PH}_3 + \text{HO}$. Form., $\text{BaO}, \text{PO} + 3 \text{HO}$, with 18.88 per cent. water. When the solution is evaporated in vacuo over somewhat dilute sulphuric acid, it crystallizes in brilliant 4-sided tables, of which the form. is $\text{BaO}, \text{PO} + 2 \text{HO}$, containing 13.44 per cent. water.

1. Perchlorate of Baryta. $\text{BaO} + \text{ClO}_7$. Ger. Ueberchloresaure Baryterde. Formed by dissolving carbonate of baryta in perchloric acid, or by precipitating perchlorate of zinc by barytic water, filtering, and evaporating; crystallizes in long prisms, deliquesces in the air, is soluble in alcohol.

2. Chlorate of Baryta. $\text{BaO} + \text{ClO}_5$. Ger. Chloresaure Baryterde. Prepared by saturating chloric acid (prepared by precipitating chlorate of potassa by silicofluohydric acid) with carbonate of baryta, and evaporating the solution. It yields 4-sided prismatic crystals, soluble in 4 pts. cold and in less hot water; insoluble in alcohol. They contain 6 per cent., or 1 eq. water of crystallization. By heat, they are decomposed into oxygen and chloride of barium. The anhydrous salt consists of 50.37 baryta and 49.63 chloric acid.

Bromate of Baryta. $\text{BaO} + \text{BrO}_3$. Ger. Bromsaure Baryterde. Obtained with bromide of barium by the action of bromine on a solution of hydrated baryta. It crystallizes in rectangular columns with replaced edges; the crystals lose their water above 392° , soluble in 130 cold and 24 boiling water. Formula, $\text{BaO}, \text{BrO}_3 + \text{HO}$, or 4.41 per cent. water.

1. Iodate of Baryta, $\text{BaO} + \text{IO}_5$, forms a sparingly soluble white powder, formed, together with iodide of barium, by treating barytic water with iodine. It then precipitates as a white powder. From a solution in hot nitric acid it separates on cooling, or by the addition of ammonia in small crystals; soluble in 1746 water at 59° , in 600 boiling; loses its crystal-water below 392° ; yields, by heat, in a porcelain retort, iodine, oxygen and 46.97 per cent. of $\frac{1}{5}$ periodate of baryta. Form., $\text{BaO}, \text{IO}_5 + \text{HO}$, or 3.57 per cent. water.

2. Periodate of Baryta, a. $\frac{1}{5}$. Formed by heating the preceding; soluble in nitric acid, not in water; formula, $5 \text{BaO}, \text{IO}_7 + 12 \text{HO}$. b. $\frac{2}{5}$. Precipitate a by ammonia, or nitrate of baryta by periodate of soda; a yellow precipitate losing its water at 302° , changing into iodate at 212° ; soluble in dilute nitric acid, not in water. Form., $5 \text{BaO}, 2 \text{IO}_7 + 5 \text{HO}$.

Carbonate of Baryta. 1. Neutral. $\text{BaO} + \text{CO}_2$. Ger. Kohlensaure B., occurs native as a mineral (see WITHERITE). Prepared by precipitating any of the soluble salts of baryta by the alkaline carbonates. Forms a white powder almost insoluble in water, requiring 4300 pts. of cold and 2300 of boiling water for its solution. It is insoluble in strong alkaline solutions, but is decomposed by solutions of muriate, nitrate, and succinate of ammonia, carbonate of ammonia being evolved; loses no carbonic acid by the strongest heat. Carbonate of baryta is often employed in analytical chemistry for

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the analysis of silicates containing fixed alkalis, for which purpose it is prepared from

	H = 1
BaO	76.6
CO ₂	22
BaO, CO ₂	98.6

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crystallized nitrate of baryta by precipitation with carbonate of ammonia. Composition :

O = 100	In 100 pts.	Schaffgotsch.
956.88	77.59	77.63
276.44	22.41	22.37
1233.32	100	100

Bicarbonate of Baryta. $\text{BaO} + 2\text{CO}_2$. Obtained by dissolving carbonate of baryta in carbonic acid water. Does not exist in solid form.

Sesquicarbonate of Baryta. $2\text{BaO} + 3\text{CO}_2$. Obtained by precipitation of a soluble salt of baryta, by sesquicarbonate of soda or potassa. Is much more soluble in water than the neutral carbonate, and by ignition loses $\frac{1}{3}$ of its carbonic acid.

Borate of Baryta is formed by mixing a soluble salt of baryta with a solution of borax. A sparingly soluble powder, which, by heat, fuses to a glass; its solution is decomposed by carbonic acid.

Silicate of Baryta. The combinations of silica with baryta fuse with difficulty and become opaque on cooling. If the fused mass contain more than $\frac{2}{3}$ baryta it is decomposed by chlorhydric acid.

SULPHOSALTS.

Sulphhydrate of Barium, $\text{BaS} + \text{HS}$, forms a very soluble salt, and crystallizes, by evaporation in vacuo, in 4-sided prismatic crystals, which are colorless; insoluble in alcohol; contain water of crystallization, which they lose by distillation. By a low redness they give off sulphuretted hydrogen, and sulphuret of barium remains as a fused mass. Exposed to the air, it effloresces, being converted into hyposulphite and sulphite.

Sulpho-carbonate of Barium. $\text{BaS} + \text{CS}_2$. Obtained by direct combination of crystallized sulphuret of barium with sulphocarbonic acid. Forms a pale yellow, amorphous salt, sparingly soluble in water, with a brownish yellow color. By evaporation in vacuo, it deposits small transparent crystals of a pale yellow color.

BARLEY. *Fr.* Orge. *Ger.* Gerste. *Tech.* The grain of several species of *hordeum*, especially *distichon* and *hexastichon*. Deprived of their husk by a mill, they form *Scotch, hulled, or pot barley*. When all the integuments of the grain are removed and the seeds are rounded and polished, they constitute *pearl-barley*. According to Einhof, 100 pts. of ripe barley grains consist of husk 18.75, meal 70.05, water 11.20. From 100 pts. of barley meal he obtained: starch and gluten 67.18, woody fibre (with some gluten and starch) 7.29, veget. albumen 1.15, gluten 3.52, uncrystallizable sugar 5.21, gum 4.62, phosphate of lime 0.24, water 9.37, loss 1.42. Fourcroy and Vauquelin detected the odorous acrid oil, to which the odor of spirit from raw grain has been ascribed, and which resides in the integuments of the grain. The *hordein* of Proust is probably nothing but bran more minutely divided and intimately mixed with starch and gluten, which are separated by the germination in malt, in which he

found it in much smaller quantity. The grains of barley starch have the same form and appearance as those of wheaten starch.

Uses. Barley, as one of the cerealia, is used as food for man and cattle. Its most extensive use is for malting (See **MALT**).

BARILLA. *Tech.* A crude soda, procured by the incineration of several marine and other plants growing on the seashore. The best, or Alicant barilla, is prepared from the *salsola soda*, which was very extensively cultivated for this purpose in Murcia and other places on the eastern shore of Spain. The plants are gathered in September, dried, and burned in furnaces, so as to bring the ashes to a state of imperfect fusion, forming a hard, dry, cellular mass of a grayish blue color. Sicily and Teneriffe produce good barilla, but inferior to that of Alicant and Carthage. The manufacture of barilla was first introduced into Europe by the Saracens in Spain. They called the plants employed in its preparation *kali*, from which the modern chemical term alkali is derived.

Uses. Formerly employed largely in bleaching operations, manufacturing hard soap, and glass making, and imported into the United States principally from the Canary Islands to the amount of \$100,000 worth annually, but of late it has been replaced by artificial soda, which will eventually destroy its production.

BARK. The outer rind of the stems of plants. The term *bark* is generally employed to express either Peruvian bark or Oak bark, which see.

BAROMETER (*βαρος, weight, and μέτρον, measure*). The instrument generally used for measuring the weight or pressure of the atmosphere. For the principles on which this instrument acts, and its different constructions, we refer to books on natural philosophy. As the volume of a gas confined in tubes, or other vessels, over mercury or water varies according to the pressure of the surrounding atmosphere, it becomes necessary in experiments on gases to observe the barometric pressure, or the height of the mercurial column in the barometer, at the time the volume of the gas is observed. Every laboratory ought, therefore, to be provided with a barometer, which should either be a good syphon-barometer or a cistern-barometer, in which the mercury of the cistern may be brought to the same level before observing the height of the column. The latter is generally read off on a scale divided into inches, tenths, and hundredths of inches. As the height of the mercurial column varies according to the temperature, a correction must be made for the temperature of the mercury in the barometer, which, for this purpose, is furnished with a thermometer to be observed at the same time. If we make *t* the number of degrees of the thermometer above the freezing

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point (32°), x the expansion of mercury for every degree of heat on Fahrenheit's scale, y the expansion of the scale of the barometer also for one degree, h' the observed height of the mercurial column; then the true height, h , which would have been observed had the thermometer stood at the freezing point, is

$$h = h' - t(x - y)h'.$$

The expansion of the mercury for one degree is 0.0001001. The difference between the expansion of the mercury and that of the scale may, with sufficient accuracy for most purposes, be considered as 0.0001. Hence the following practical rule for reducing an observed height to the corresponding height at the temperature of the freezing point: subtract from the observed height the number of degrees of the observed temperature above 32 , multiplied first by 0.0001, and then by the observed height itself. Suppose the observed height to be 30 inches and the thermometer to indicate 54° , the correction will be $(54 - 32) \times 0.0001 \times 30 = 0.066$, to be subtracted from the observed height, or 30 inches.

BARSOVITE. *Min.* It occurs amorphous, granular, sometimes cleavable in one direction, sometimes compact with a splintery fracture. Snow-white; sub-translucent; lustre of the granular faint pearly, of the compact dull; $H. = 6$. $G. =$ of granular, 2.752, of compact, 2.74.

Behavior. Fuses with difficulty on the edges, with slight intumescence, to a vesicular glass; dissolves to a clear glass in borax and mic. salt, leaving a skeleton of silica in the latter; with an equal quantity of soda it fuses to a vesicular glass, and with more soda is infusible. It is readily decomposed by muriatic acid when heated, yielding gelatinous silica.

Analysis by Varrentrapp:

Silica.....	49.01
Alumina.....	33.85
Lime.....	15.46
Magnesia.....	1.55
	99.87

Including the magnesia with the lime the formula is $3 \text{CaO}, 2 \text{SiO}_3 + 3 (\text{Al}_2\text{O}_3, \text{SiO}_3)$. It, therefore, approaches scapolite which contains only 2 equivs. of the aluminous silicate.

Locality. Found in the gold-sand washings of Barsowskoj near Kyschtimsk in the Ural, associated with blue sapphire, greenish black zeilanite, and white mica.

BARYTO-CALCITE. *Min.* Hemiprismatic Hal-baryte, *Mohs.* *Description.* Cryst. system, Oblique Rhombic, the vertical prism M on $M = 106^\circ 54'$ and $73^\circ 6'$; M on base $P = 102^\circ 54'$; cleaves perfectly parallel to M , less easy parallel to P . It also occurs massive. Grayish, greenish, or yellowish white; lustre vitreous, inclining to resinous; transparent, translucent; streak white; fracture uneven.

Behavior. Yields moisture in a closed tube; ignited on charcoal, becomes at first white and opaque (in a very strong fire it is covered with a greenish glass, and slightly colors the flame yellowish green, *Kobell*), becomes caustic and yields a brown spot when moistened on silver;

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borax and mic. salt dissolve it with effervescence, and in quantity to a clear glass, becoming hyacinth-colored on cooling, and when mineral and salt are in equal bulk, it becomes cloudy on cooling; with soda it is decomposed, leaving a portion on the surface of the charcoal as a hepatic slag. Soluble in acids with effervescence.

Analysis. 1. From Alstonmoor, by Children; 2. by Richardson.

	1.	2.
Carbonate of baryta.....	65.9	62.20
Carbonate of lime.....	33.6	31.65
Sulphate of baryta.....	—	0.30
Peroxide of iron.....	—	0.85
Volatile matter.....	—	3.45
	99.5	98.45

It therefore consists of one equivalent of each carbonate, and its formula is $\text{BaO}, \text{CO}_2 + \text{CaO}, \text{CO}_2$. Thomson described a bicalcareo-carbonate of baryta with the formula $2 (\text{CaO}, \text{CO}_2) + \text{BaO}, \text{CO}_2$, and a different crystalline form, which Johnston has shown to be identical with barytocalcite in form and composition. According to Johnston, a mineral occurring at Fallowfield near Hexham in Northumberland and at Alstonmoor, has the same composition as barytocalcite, although belonging to the doubly oblique rhombic system.

Locality. At Alstonmoor in Cumberland in the lead-mines in considerable quantity.

BARYTO-CELESTINE. *Min.* Color white, with bluish tint; structure lamellar, radiated; $H. = 2.75$. $G. = 3.921$. Difficultly fusible before the blowpipe; with borax gives an opaque bead. It consists of sulphate of strontia 63.2, sulphate of baryta 35.2, protoxide of iron 0.59, water 0.72. If the analysis be nearly correct, its formula is $2 (\text{SrO}, \text{SO}_3) + \text{BaO}, \text{SO}_3$; but it would seem that several of the analyses by Thomson of these barytic minerals have been shown to be erroneous. It occurs on Drummond Island, Lake Erie, and at Kingston, U. C. The description and analysis by Thomson.

BASACIGEN. The term of basacigen substances has been applied by Dr. Hare to those elements which, by combining with other elements, are capable of producing both acids and bases. This term has therefore the same meaning as Berzelius's *amphigen bodies*, or *both producers* (see *Amphigen*); but Dr. Hare comprises under his basacigen bodies also the halogen bodies of Berzelius. The basacigen bodies of Dr. Hare are oxygen, chlorine, bromine, iodine, fluorine, sulphur, selenium, tellurium, and the compound body cyanogen. Oxygen is thus called a basacigen body, because by combining, for instance, with carbon, it forms an acid, carbonic acid ($\text{C} + \text{O}_2$), and with potassium a base, potassa ($\text{K} + \text{O}$); sulphur is another basacigen body, because, in the same way, by combining with carbon, it will produce a sulph-acid sulphocarbonic acid (CS_2), and with potassium a sulpho-base, the sulphuret or sulphide of potassium ($\text{K} + \text{S}$).

BASALT. *Geol.* A species of trappean or igneous rock, considered as of a comparatively modern date. It sometimes constitutes insulated mountains of a conical form and con-

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siderable altitude, but never forms by itself extensive mountain chains. It is most usually incumbent on other rocks and often constitutes the summits of mountains, the greater part of which are composed of materials totally different from basalt.

External Characters. Basalt is never crystalline, and occurs either in large amorphous masses or under a columnar, tabular, or globular form; sometimes its structure is amygdaloid or vesicular. It is of a gray, or brownish, or bluish black color; exteriorly it is often brownish from decomposition. Streak light-gray, lustre dull, and uneven or conchoidal fracture. Opaque, or feebly translucent at the edges. It yields to the knife, but is difficult to break. Spec. gravity varies from 2·87—3·00. Before the blowpipe it melts into an opaque glass, which is often attracted by the magnet.

Chemical Composition. Basalt consists of an intimate mixture of a number of other minerals, among which may be distinguished augite or hornblende, labradorite or nephelin, magnetic and titaniferous iron ore, olivine and one or more zeolites, all of which often occur separated in the basalt. C. Gmelin was the first to show that basalt consists of two portions, one of which is decomposable by acids, the other not. All later chemical investigations have been based on this fact, but without yet being able to separate or distinguish, with sufficient accuracy, the different minerals of which it is composed; for, if a dilute acid be employed, olivine and magnetic iron ore are only imperfectly decomposed, while, by a stronger acid, portions of augite and labradorite are, at the same time, also attacked. From the same reason, it is also difficult to determine the particular species of zeolite which it contains. Basalt is distinguished from lava by its content of water, which averages about 2·5 per cent., and of which lava only contains hygroscopical portions.

The following analyses of German basalt will convey an adequate idea of its general composition. 1. Basalt from Stolpen, analyzed by Sinding; 2. from Steinsburg near Suhl in Thuringia, by Petersen; *a.* the portion decomposed by chlorohydric acid; *b.* the portion undecomposed in each.

	1.		2.	
	<i>a.</i> , (soluble)	57·736	<i>a.</i> , (soluble)	42·5
	<i>b.</i> , (insoluble).....	42·264	<i>b.</i> , (insoluble).....	57·5
	100	100	100	100
	1 <i>a.</i>	<i>b.</i>	2 <i>a.</i>	<i>b.</i>
Silica	39·920	52·62	37·25	61·63
Alumina	21·266	11·93	8·82	14·28
Peroxide of iron ..	9·318	10·63	11·76	—
Protox. of iron ..	7·482	—	18·47	7·54
Magnesia	4·379	8·26	10·29	5·50
Lime	7·857	15·49	6·61	6·03
Soda	5·279	—	0·05	3·92
Potassa	2·795	—	4·17	1·10
Water	2·490	—	3·69	—
	100·786	98·93	101·11	100

Of these the decomposable portion, *a.* might be calculated to consist of

BASIS.

	1 <i>a.</i>	2 <i>a.</i>
Zeolite	74·837	47·16
Olivine	12·630	36·91
Magnetic iron	13·318	17·04
	100·785	101·11

Of the undecomposable portion it is still more difficult to conjecture the mixed composition, but it may possibly be augite and labradorite.

Columnar basalt constitutes the Giant's Causeway near Cape Fairhead, Ireland, and the sides and roof of the celebrated cave of Fingal on the Island of Staffa. It is doubtful whether any true basalt has yet been observed in the United States.

BASALTIC HORNBLLENDE. This appellation has been given particularly to those cleavable and highly crystalline black hornblendes, which occur in basaltic and amygdaloidal rocks (see **HORNBLLENDE**).

BASANITE. *Min.* See **QUARTZ**.

BASANOMELANITE. *Min.* See **TITANIFEROUS IRON**.

BASE, or BASIS. *Chem.* Any substance capable of combining with acids, and neutralizing more or less their acid properties, and thus forming salts with them. Every true salt, therefore, consists of an acid and a base, or, in electro chemical language, of an electronegative and electropositive ingredient (see under **SALTS**). The alkalies possess, therefore, in the highest degree, the character of bases, and the latter word is only a wider extension of the term alkali, from the supposition that the alkaline ingredient of a salt constituted its most important and characteristic part, or the basis of it. For the same reason, the term basis is often, but less frequently, extended to the electropositive element of the alkalies themselves, or of any other binary compound, in which latter sense it becomes synonymous with *radical* (see this); thus, potassium is said to be the metallic *basis* or radical of potassa (oxide of potassium) and of chloride of potassium.

As the term salt was extended beyond oxy-salts to other ternary compounds, such as sulphosalts, chlorosalts, &c., it has also become necessary to extend the term base to the electropositive ingredient in these salts, and we thus distinguish between oxy-bases, sulpho-bases, chloro-bases, &c. (see *Basigen bodies*). Thus, *oxide of copper* is an *oxy-base*, because it combines with oxacids, such as arsenic acid, forming an oxysalt, the arseniate or, more correctly, the oxy-arsenate of copper ($2\text{CuO} + \text{AsO}_5$), while the sulphuret of copper is a sulpho-base, combining with sulph-acids as, for instance, with sulpharsenic acid to a sulpho-salt, the sulpharsenate of copper ($2\text{CuS} + \text{AsS}_5$), &c.

Under the term oxybases, or simply *bases*, as they often are called, where no reference is made to other kinds of bases (such as sulpho-bases, &c.), are therefore comprehended the alkalies, the alkaline earths, the earths (see these), and all those oxides which are capable of combining with, and more or less neutralizing oxacids, and forming salts with them, such as the oxides of iron, copper, &c., for

which we refer to the different metals. To this class of bases belong also a class of organic nitrogenous substances mostly obtained from plants, or artificially produced, which have all the properties of the metallic or inorganic bases, and are capable of replacing them in their combinations. These are termed *vegetable alkalies* or *alkaloids* (see ALKALOID), but their character as oxides or oxybases is even more doubtful than that of ammonia (or oxide of ammonium), with which they seem to have an analogous constitution, while their basic properties, at the same time, seem dependent on the amount of nitrogen which they contain. The oxides of ethyl (ether) and methyl form another class of organic bases, which may be combined with acids and neutralize their acid properties, and are therefore also called organic bases, but their combination with the acids differ considerably in their nature from the ordinary inorganic salts by not allowing their acids or bases to be replaced or exchanged, with the same facility, by single or double affinity for other bases or acids.

BASSORIN. *Chem.* An insoluble, gummy principle found in Tragacanth and other gums. See GUM.

BATH. *Chem.* An apparatus for communicating a uniform heat to bodies by surrounding them with a fluid or a pulverulent substance, on which the heat is made to act, instead of applying it directly to the bodies themselves. The object of heating substances in a bath is to obtain a more uniform and steady temperature than can be obtained by exposure to an open fire, and to avoid all accidents to which they might be liable from the inequality and suddenness of the heat, such as cracking of the containing vessels, decomposition of portions of the contained substances from greater heat in one place than in others, violent ebullitions, spiritings, &c. Substances, which are employed for this purpose, are sand, fusible metals, solutions of salts, water, alcohol, air, steam, &c.

Sand-bath. Every laboratory is generally supplied with a larger sand-bath for general purposes, such as digestions, evaporations, &c. (See LABORATORY.) For special purposes, such as distillations, digestions, &c., any iron or copper dish or pot will answer, in which the vessel to be heated is placed on the bottom, with the intervention of a thinner or thicker layer of sand, and then the rest of the space between the vessel and the sides of the dish filled with sand as high up as desired, and the whole heated by being placed over the fire of a furnace. The movable furnaces of the laboratory are usually furnished with sheet or cast iron sand-baths of different sizes, which may be fitted on them when required, and allow of a better regulation of the draft (see under FURNACES, *Chemical*). The sand used for these purposes should be good sea or river-sand, washed thoroughly to remove all dirt, and dried.

Magnesia is often used as a bath. When platinum or porcelain crucibles or retorts are to be heated to ignition in a coal-fire, and especially if it be required to weigh them after the ignition, they may be placed in a hessian cru-

cible and surrounded with pure magnesia, so as to prevent them from touching the outer crucible in any place. The magnesia remains perfectly infusible, and attacks neither the outer nor inner crucible, and, even if the heat be raised so high as to soften the outer crucible, the inner vessel remains perfectly loose and clean. The magnesia may be used again for the same purpose. It may, however, be remarked that common carbonate of magnesia or magnesia alba of the shops, from which the magnesia is prepared by ignition, generally contains carbonate of soda, which may attack the inner vessel, and should, therefore, first be removed by washing with water after the ignition, and the magnesia then again ignited.

Metallic baths. Mercury may be used as a bath for low temperatures, and up to 450°. But beyond this temperature it should not be employed in open vessels, for the metal soon rises in vapor, and the fumes not only occasion waste of mercury, but produce also injury both to the experiment and more especially to the health of the operator. For this latter reason it is employed but rarely.

An excellent metallic bath is afforded by *fusible metal*, which is obtained by fusing together 8 pts. of bismuth, 5 of lead, and 3 of tin. At ordinary temperatures it is solid, but it melts at a heat below 212°. At a dull redness thick films of oxide form on its surface, which increase with its temperature, but it will bear even a white heat without evolving fumes. Tin and lead are both good metals for temperatures above their fusing points; the first melts at 441°, the other at 609°.

These metallic baths answer well for small experiments, but, when larger, great inconvenience is experienced from the weight of the metal, both in its support and in keeping the vessels to be heated immersed in it. For safety, the metal should always be heated in iron vessels, such as iron crucibles or pots, or cast iron saucepans.

By employing mixtures of lead and tin in different proportions, and heating them just to fusion, we have points of temperature which are nearly constant, and may be employed conveniently in the arts. The following table from Parkes' *Chem. Essays* exhibits some of these proportions, with their fusing points, by which hardened steel may be tempered, according to the nature of the instrument or tool manufactured.

	Lead.	Tin.	Temp.F.
Lancets.....	7	4	420
Razors, &c.....	8	4	442
Penknives, &c.....	8½	4	450
Penknives, larger, &c....	10	4	470
Scissors, Shears, &c.....	14	4	490
Axes, Plane irons, &c....	19	4	509
Table-knives, &c.....	30	4	530
Watch-springs, Swords, &c.	48	4	550
Large springs, Augers, &c.	100	4	558

Chloride of Zinc has lately been much recommended as a bath for higher temperatures. It forms a deliquescent salt, which retains its

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water with great force, and may therefore be heated beyond 212° without ebullition, but at 320° the concentrated solution begins to boil and give off chlorohydric acid fumes, which inconvenience the experimenter and cause a great deal of spitting and frothing. It may be heated in cast-iron vessels.

For lower temperatures, but still higher than that of boiling water, *solution-baths* of different salts are employed. They have the advantage of being easily prepared in sufficient quantity without great expense, and afford a range of 20 to 30 degrees above the boiling point of pure water. The following table exhibits the boiling point of a saturated solution of some of the salts most usually employed for this purpose:

	Boiling point.
Bitartrate of potassa.....	214°
Alum.....	220°
Borax.....	222°
Common salt.....	224°
Tartrate of potassa.....	234°
Chloride of ammonium.....	236°
Nitre.....	238°
Rochelle salt.....	240°
Chloride of calcium.....	355°

Oil-bath. When the required temperature is above the boiling point of water, but does not surpass that at which fatty oils are decomposed, these liquids afford the most convenient fluids for baths. The only inconvenience in their use is the disagreeable odor of their vapor, especially when heated up towards their boiling point, or about 570° , at which temperature they suffer a simultaneous decomposition. Even in many cases, where a lower temperature is desired, oil-baths are to be preferred to water-baths, on account of the facility with which the temperature can be regulated by an immersed thermometer, while, at the same time, they are not subject to the inconvenience arising from the evaporation of the water, when not replenished. The oil is heated in vessels of iron or copper, either over coal-fire, or, more conveniently, over an argand spirit, oil, or gas-lamp.

Water-bath. *Fr.* Bain d'eau, Bain-marie. *Ger.* Wasserbad, Marienbad. Employed in most cases where the required temperature does not surpass 212° . The simplest kind of water-bath may be formed by any two vessels placed the one in the other, and water poured between them. But the inner vessel should not touch the bottom of the outer vessel, otherwise heat might be conducted from it through the points of contact, and the temperature in the inner vessel rise considerably above that of the surrounding water. Nor should the inner vessel be allowed to float in the water so as to endanger it or its contents by striking against the bottom of the outer one when the water becomes boiling. For ordinary purposes these inconveniences may be avoided by putting some straw and tow at the bottom of the outer vessel. Common tin cups, or tin saucepans, surmounted by a porcelain capsule, afford, in many cases, an extremely convenient water-bath for evaporations. Fig. 30 represents a small saucepan converted into an extemporary water-bath for the heating of three

BATH.

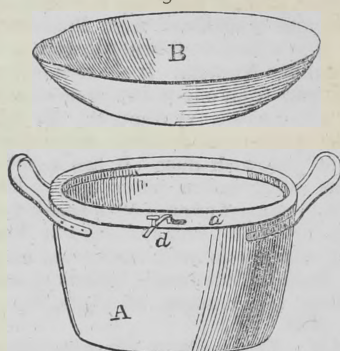
Fig. 30.



small flasks, kept in their places by holes in the lid, through which their necks are protruded. But their frequent use in the laboratory, for evaporations and other purposes, renders it, in most cases, necessary

to have one or more water-baths made for the purpose. The smaller ones are best made of thin sheet-copper, somewhat of the shape of a common sauce-pan, but with an inner flange at the top to support the lids, made of circular pieces of sheet copper, with apertures of different diameters in their centre, according to the size of the evaporating dish or other vessel to be heated in the bath. Near the top they may be furnished with a small tube to allow the steam or the water to escape in case of too violent ebullition. Fig. 31 repre-

Fig. 31.



sents a larger water-bath. A is the vessel containing the water, a the inner flange for the support of the evaporating dish B, or different circular rings when smaller dishes are employed. d is a tube furnished with a stop-cock for the escape of the steam, which, in some cases, requires to be carried still farther off by an additional tube attached to it. The whole apparatus may be heated either by a gas-stove (see ANALYSIS, § 17, Fig. 22) or on a charcoal furnace. The water-bath is filled about half-full with water. It will be seen that water-baths with cover act more on the principle of steam-baths as soon as the quantity of water which they contain is small. Care must be taken always to replenish the evaporating water by adding fresh, otherwise not only the experiment may be ruined, but the bath itself become seriously injured.

Where a certain constant temperature is to be kept up, this ought always to be regulated by a thermometer immersed in the bath, to which purpose those thermometers are best adapted which have the scale marked on the stem itself (see THERMOMETER). The temperature of the bath may either be tried at different times by immersing the thermometer carefully into the bath, or the thermometer may be suspended in it from a hook, or fixed by a cork through a separate tube in the cover of the water-bath. It must, however, be remembered that the substance heated in the bath never acquires the same temperature as the latter, and that this difference in temperature

often is very considerable where the substance is contained in porcelain or glass vessels, as, for instance, by distillations in glass retorts. In such cases, the bath ought always to be covered, and, if necessary, the heat inside the retort ascertained, by fixing a thermometer through the tubulure of the retort.

BATRACHITE. *Min.* See OLIVINE.

BDELLIUM. This term is applied to two gum-resinous substances. One of these is the *Indian bdellium*, or *false Murrh* (the *Bdellium* of scripture), which is obtained from *Amyris* (*Balsamodendron*?) *Commiphora*. The trunk of this tree is covered with a light-colored pellicle, as in the common birch, which peels off, and is often found adhering to the pieces. The tree diffuses a grateful fragrance like that of the finest murrh to a considerable distance around. Indian bdellium has considerable resemblance to murrh. Many of the pieces have hairs (of the goat?) adhering to them. The other kind of bdellium is called *African bdellium*, and is obtained from *Hendolotia Africana*. It is a native of Senegal, and is called by the natives Niottout. It consists of rounded or oval tears from one to two inches in diameter, of a dull and waxy fracture. By age they become opaque, and covered externally by a white or yellowish dust. It has a feeble, but peculiar odor, and a bitter taste. Pelletier found it to consist of *resin* 59.0, *soluble gum* 9.2, *bassorin* 30.6, *volatile oil* and *loss* 1.2. The gum yielded, with nitric acid, oxalic but no mucic acid. Resin of bdellium (*African*?) consists, according to Johnston, of $C_{40}H_{31}O_5$. *Phil. Trans.* 1839.

BEAN. The seeds of *Phaseolus vulgaris*, or common kidney-bean, consists, according to Einhoff, of—

In 100 pts.

Starch.....	35.94
Gluten, cont. some starch, fibres, and phosphate of lime.....	20.81
Vegetable albumen.....	1.35
Bitter extractive, soluble in alcohol.....	3.41
Gum, with phosphate of potassa and chloride of potassium.....	19.37
Fibrous, starchy matter.....	11.07
Skins.....	7.5
Loss.....	0.55

According to the analysis of Braconnot, they contain—

Starch.....	42.34
Gluten (legumin, Braconnot).....	18.2
Mucilaginous matter, containing nitrogen, precipitable by tannin,...	5.36
Pectin.....	1.5
Yellow, fatty matter.....	0.7
Sugar.....	0.2
Phosphate and carbonate of lime, phosphate of potassa.....	1.0
Starchy, fibrous matter.....	0.7
Skins.....	7.0
Water.....	23.0

Composition of the Skins.

Vegetable fibre.....	6.4
Pectic acid.....	1.23
Matter soluble in water, with some starch and gluten.....	1.17

The seeds of *Vicia faba* (field bean) contain,

according to Einhoff, in 100 pts., starch 34.17, gluten 10.86, albumen 0.81, bitter extractive 3.54, gum 4.61, starchy, fibrous matter 15.89, phosphate of lime and magnesia 0.98, skins 10.05, water 15.63, loss 3.46.

BEARBERRY. *Tech. Phar.* *Arbutus Uva-ursi*. The leaves of *uva-ursi* contain a large amount of tannin, and belong, therefore, to the class of vegetable astringents. According to the analysis of Meissner, they contain gallic acid 1.2, tannin 36.4, resin 4.4, extractive, with some supermalate and citrate of lime and traces of chloride of sodium 4.2, gum 15.7, extractive, obtained by potash, and containing pectic acid and tannin, 17.6, lignin 9.6, water 6. The tannin belongs to that class which precipitates the salts of iron with a black color.

Use. Bearberry is used in tanning. The leaves are used in medicine, and combine with their astringent properties a peculiar influence over the urinary organs, especially in chronic affections of the bladder.

BEE. The venom of the bee, according to Fontana, bears a close resemblance to that of the viper. It is contained in a small vesicle, and has a hot and acrid taste like that of the scorpion.

BEER. *Fr.* Bière. *Ger.* Bier. *Tech.* The fermented infusion of malted barley, flavored with hops, and used as a general beverage. The name of beer is also applied, but improperly, to several other beverages made from saccharine liquors, subjected to a partial fermentation, and flavored with different substances, for instance, spruce beer, ginger beer, molasses beer.

Manufacture. The manufacture of beer, or the art of brewing, forms an extensive branch of manufacturing industry, and may be considered under the following heads:

1. The conversion of the barley into malt, or the process of *malting*.
2. The formation of a proper wort from the malt and hops, or the process of *mashing, boiling, and cooling*.
3. The fermentation of the wort, to which may yet be added the ripening and preservation of the beer.

1. *Malting.* For the conversion of barley into malt. (See MALT.) It often forms a separate branch of industry.

2. *Mashing, Boiling, and Cooling.* *Mashing* is the operation by which the malt is extracted, and a saccharo-mucilaginous extract made from it called *wort*.

The malt is first crushed on a crushing-mill between iron rollers, or ground on a grist-mill. In the latter case it is generally sprinkled with water 12 to 24 hours previously, in order to render the husk more tenacious. It should, in general, not be ground to a fine meal, for in this case it is apt to form a cohesive paste with hot water, or to *set*, as it is called, and to be difficult to drain. In crushed malt the husk remains nearly entire, and thus helps to keep the farinaceous particles open and porous to the action of the water. The bulk of the crushed malt is about one-fifth greater than that of the whole, or one bushel of malt gives a bushel and a quarter of crushed malt. It is then frequently allowed to lie a few days in a

cool place, in order that it may attract moisture from the air by its hygroscopic properties, and thus, from being hard and indurated from the drying in the kiln, become soft and spongy, and easily penetrated by the water in the subsequent process of extraction or mashing.

a. Mashing has not for its object merely to dissolve the sugar and gum already present in the malt, but also to convert the starch, which remains unchanged during the germination, into a sweet mucilage, by the diastase which has been formed by the process of germination; for the latter substance (see *DIASTASE*) possesses the property, by digestion with water at a temperature from 150° to 167° and over, of converting starch into a mixture of sugar and gum. This, therefore, gives the range of temperature which ought to be maintained in the operation of mashing; but it has been found advantageous to begin with water at a lower temperature and to conclude with water at the highest, performing the operation with separate portions and by degrees.

Pl. II. Fig. 2, represents an English mashing machine. The mash-tun, *a, a*, is a large circular tub with a double bottom, the uppermost of which is called a false bottom, and is pierced with many holes, leaving a space of about two or three inches between the two bottoms, into which the stop-cocks enter for letting in the water and drawing off the wort. The mash-tun is provided with a rotatory apparatus for agitating the crushed grains and water together, consisting of a perpendicular shaft *b* in the centre of it, which is turned slowly round by means of the bevelled wheels *t, u*, at the top. *c, c* are two arms projecting from this axis, and supporting the short vertical axis of the wheel, *x*, so that when the central axis, *b*, is made to revolve, it will carry this axle around the tun in a circle. This axle is furnished with a number of horizontal arms or blades *e, e*, placed obliquely to the plane of their motion, which, when turned round by the axis and wheel *x*, agitate the malt in the tun, and give it a constant motion upward from the bottom.

The motion of the last mentioned axle is produced by the wheel *x*, on the upper end of it, which is turned by a wheel *w*, fastened on the middle of the tube *b*, which turns freely round upon the central axis. Higher up, on the same tube *b*, is a bevel wheel, *o*, receiving motion from the bevel wheel *q*, fixed upon the end of the horizontal axis *n, n*, with a pinion, *p*, on its centre which gives motion to the wheel *r*, so that the horizontal axis, *s, s*, is turned, and motion communicated through the bevel wheel *t*, to *u* and its axis, as before mentioned. It will thus be seen, that by the horizontal axis, *n, n*, motion is communicated to the two perpendicular axes in the mash-tun, by which the axle with its blades is made to travel round in it, and at the same time its blades to revolve upon it at a much faster rate, making 17 or 18 revolutions while carried once round in the tun by the motion of the shaft *b*; *h* and *i* are two bevel wheels fixed on a tube, which, by the levers, *k, k*, is made to slide up and down on its axis, and thus to bring either of the wheels in connection with the horizontal axis *n, n*, and thereby im-

part to the whole apparatus a quicker or slower motion, as required.

When the mash is to begin, water is first heated in the copper, and then let into the mash-tun. The temperature of this first water may be, in winter, 140° , in summer, 113° . Its quantity depends on the quantity of crushed malt, with which it should form a rather thick paste, the object of this first water being merely to moisten the malt uniformly, that no lumps remain, for which purpose the crushed malt is gradually thrown in, and well intermixed by proper agitation. In this way the mixture remains for half to three quarters of an hour. The first mashing water which, in, the meanwhile, has been heated to boiling in the copper, is then run into the mash-tun, and mixed well with the mass by renewed agitation, in sufficient quantity till the whole has assumed the temperature of about 150° . The tun is now to be well covered, for the preservation of its heat, and allowed to remain at rest for about an hour or more, in which time the remaining starch is first converted into dextrine and then into sugar; but the time which may be allowed for this purpose varies according to the quality of the malt, and other circumstances. Leaving it too long time at this temperature would give rise to the formation of lactic acid from the starch and sugar (see *FERMENTATION, lactic*), by which a quantity of gluten would be dissolved in the wort, and cause the conversion of a large portion of alcohol into acetic acid during the subsequent fermentation. This occurrence does not take place equally soon under all circumstances. A high temperature of the atmosphere favours it, especially when charged with electricity. It is also less apt to take place with kiln-dried and dark malt than with pale, owing, probably, to the presence of empyreumatic oil in the former, which prevents the decomposition of the nitrogenized substances by which the lactic fermentation is induced.

The tap of the tun is then opened, and the wort drawn off. If that which first flows be turbid, it must be returned into the tun till it runs clear. The wort is mainly a solution of starch, sugar, and gum, with some gluten, and albumen, of an agreeable sweetish, and when made from kiln-dried malt, of a peculiar aromatic taste. Its strength or concentration depends mainly on the quantity and temperature of the water employed in the first instance for the drenching of the dry malt, since the subsequent mash-water must be added in such quantity as required to raise the heat to the proper temperature for the saccharification of the starch.

A considerable quantity of the wort remains in the drained mash, to the amount of 125 lbs. wort in the mash from 100 lbs. malt. To obtain this, a new portion of boiling hot water is introduced into the tun, and the mixture agitated till it becomes uniform as before. The temperature of this mash is made higher than the first, and may be raised to 167° , or more. After the mash has rested the proper time, as before, the second wort is then drawn. Only in case of great concentration of the first wort, a third wort may be drawn, for even for weak beers the wort requires to have a spec. grav.

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of 1.030, and the expense and inferior quality of the product would not warrant much concentration by boiling. The second wort is either added to the first, or brewed by itself into an inferior beer. The exhausted malt is used as food for cattle.

b. Boiling of the wort, and addition of the hops. The wort should be transferred into the copper and made to boil as soon as possible, otherwise it is apt to become acescent, but, as soon as it is boiling the higher temperature destroys the lactic fermentation, while, at the same time, the steam that rises from it serves to protect it from the oxydizing influence of the atmosphere. Until it begins to boil, the air should, therefore, be excluded as much as possible. It is hence better to have two coppers, one for the boiling of the wort, the other for heating the water for the second mash.

The object of boiling the wort is not merely evaporation and concentration, but also coagulation and precipitation of the albumen and other nitrogenized substances, and its combination with the hops, which latter purposes are better accomplished in a deep confined copper than in an open pan. Pl. II. Fig. 3 and 4, represent the copper of a London brewery, Fig. 3, being the vertical section, and Fig. 4, a ground plan of the fire-grate and flue. *a*, is the close copper kettle, having its bottom convex within; *b*, is an open pan placed on its top for heating water or a weaker wort at the same time by the waste steam. From the upper part of the copper, a wide tube, *c*, ascends, to carry off the steam generated during the ebullition of the wort, which is conducted through four downward slanting tubes, *d, d*, (two only being visible in the section,) into the contents of the pan *b*, which is thus heated. A vertical iron shaft or spindle, *e*, passes down through the tube *c*, nearly to the bottom of the copper, and is there mounted with an iron arm called a *rouser*, which carries round a chain hung in loops, to prevent the hops from adhering to the bottom of the boiler. Three bent stays, *f*, are stretched across the interior, to support the shaft by a collet at their middle junction. The shaft carries at its upper end a bevel wheel *g*, working into a bevel pinion upon the axis *h*, which may be turned either by power or by hand. The rouser-shaft may be lifted by means of the chain *i*, which, going over two pulleys, has its end passed round the wheel and axle *k*, and is turned by a winch. *l*, is a tube for conveying the waste steam into the chimney *m*. The copper is heated by two separate fires with a narrow brick wall, *n*, Fig. 4, between them, *oo* are the grates upon which the coals are thrown through a short slanting iron hopper, *p*, Fig. 3, kept continually filled with the fuel, in order to exclude the air. Above the hopper, *p*, a narrow channel is provided for the admission of atmospheric air, in such quantity as is merely sufficient for the combustion of the smoke of the coal; *rr* are the fire bridges by which the fires are made to play upon the bottom of the copper. The hot air then passes round the copper in a semi-circular flue *ss*, into the chimney *m*.

As soon as the temperature of the wort is raised towards the boiling point, the albumen begins to separate, and by the subsequent boil-

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ing, to collect in lumps. The time of boiling the wort depends on several circumstances. In the first place, the separation of all precipitated matter must be completed, the wort must be sufficiently concentrated, and the hops have been added sufficiently long. The first is ascertained by inspection of portions drawn out by a proof gauge, when the separated albuminous flocks settle speedily, and leave the supernatant liquid clear.

The concentration of the wort is ascertained from separate portions by a hydrometer, which is often peculiarly constructed for this purpose, and is called a saccharometer, indicating by how many pounds a barrel of that wort is heavier than a barrel of water, or how much *saccharine* it contains per barrel. It is better to have the hydrometer to indicate directly the specific gravity or the percentage of dry malt extract which it contains, and which Balling has found to be the same as that of sugar for the same specific gravities, according to the following table, the temperature being $63\frac{1}{2}^{\circ}\text{C}$, to which temperature, therefore, the proof must be cooled down:

Spec. Grav.	Per cent. of Malt extract.	Spec. Grav.	Per cent. of Malt extract.
1.012	3	1.057	14
1.016	4	1.061	15
1.020	5	1.065	16
1.024	6	1.070	17
1.028	7	1.074	18
1.032	8	1.078	19
1.036	9	1.083	20
1.040	10	1.087	21
1.044	11	1.092	22
1.048	12	1.096	23
1.053	13	1.101	24

There is usually dissipated one-sixth or one-seventh part of the water in the boiling copper, and two or three hours boil is deemed long enough in many well-conducted breweries; but it must of course be regulated by the nature of the wort and the quality of the beer. The specific gravity of the wort for ale is usually about 1.090 to 1.100, and for table beer from 1.020 to 1.030. In regard to the proper concentration of the wort, it is to be observed, that this is still more increased by evaporation during the subsequent cooling, which evaporation is generally considered to amount to $\frac{1}{10}$, or an increase in malt extract of from 1 to $1\frac{1}{3}$ per cent.

The amount of dry malt extract obtained from 100 parts of kiln-dried malt may be considered to amount to about 60 per cent. Malt that has been kept for a long time, and abstracted a great deal of moisture, will of course yield less. According to this, if we call the percentage of malt extract in the wort *p*, the quantity of wort of a certain strength obtainable from 100 lbs. of malt will be = $\frac{60 \cdot 100}{p}$ lbs. 100 lbs. of malt will thus yield, of wort containing 12 per cent. of malt extract $\frac{60 \cdot 100}{12} = 500$ lbs.

The *hops* are added during the progress of the ebullition about an hour before the wort has acquired the proper concentration. They

not only serve to give the beer a better aromatic taste, but destroy also its tendency to become sour, and thus impart to it a keeping property—an effect partly due to the precipitation of different soluble matters by the resinous and astringent principles of the hops, and partly to the antiseptic properties of its aromatic principle. In this respect there are none of the bitter plants which can be substituted for hops with advantage. The hops should be thrown upon the surface of the boiling wort and remain there for some time, in order to be penetrated by the steam, and thus become extracted more readily when pushed down into the liquor. The quantity of hops to be added varies, according to the strength of the beer and other circumstances, from $\frac{3}{4}$ to 3 lbs. for every 100 lbs. of malt. In order to avoid a loss of the aromatic principle of the hop by the boiling, it has been preferred merely to make an infusion of the hops by hot water, or by a portion of the hot wort, and to add this infusion to the wort in the fermenting tun, but it has been found that boiling improves the bitter taste imparted by the hops.

During the boiling, the sweetness of the wort is increased considerably, partly from the concentration and partly from the conversion of the starch-sugar into uncrystallizable sugar, which has a sweeter taste. At the same time the color of the wort becomes darker, so that for some very dark and sweet German beers the boiling is continued, for this reason, for 12 to 15 hours. For pale beers it is, on the contrary, an object to perform the concentration and clarification in as short a time as possible. The latter is in some cases accelerated by the addition of some gelatine in the form of calf's foot or isinglass.

c. Cooling. When the hops are sufficiently extracted and the wort concentrated and clear, the boiling is stopped and the wort drawn off into what is called the hop-back, on the upper part of which is fixed a drainer to keep back the hops. The wort is then generally raised by pumps to the coolers, placed in an airy situation, it being of great consequence to cool the worts down to the fermenting pitch as fast as possible. The common cooler is a square wooden cistern about 6 inches deep, and of such an extent of surface, that the whole of one boil may only occupy about 2 inches of depth in it. The seams of the cooler should be made perfectly water-tight and smooth, so that no liquor may lodge in them when they are emptied. The utmost cleanliness is required, and an occasional sweetening with lime water. The wort generally reaches the cooler at a temperature from 208°—200°, where it should be cooled down to the proper temperature for the fermenting tun, which may vary from 54° to 64°, according to circumstances. The refrigeration is mainly accomplished by the evaporation of a portion of the liquor, and is therefore more rapid in proportion to the extent of the surface, and to the temperature and the dryness of the atmosphere surrounding the cooler. The latter should therefore be placed so as to have its surface freely exposed to the prevailing wind or draft of the locality, and the vapors may in many cases be advantageously carried away by

the agency of a fan. Agitation of the wort during its cooling is by many considered as hurtful. The rapid cooling is of great importance in regard to the quality of the beer, on account of the readiness with which it otherwise absorbs oxygen and passes into the acetous fermentation with the formation of various other products to which ill-hopped beer is peculiarly liable. The period of refrigeration in a well-constructed cooler amounts to 6 or 7 hours in favorable weather, but under other circumstances to 12 or 15 hours. The wort generally deposits a slight yellowish sediment in the cooler, which consists of a combination of starch with tannin, which is only soluble in the hot wort, and separates on cooling, and from which the wort should be cautiously separated. A good wort should always be perfectly limpid, for a muddy liquor never produces a transparent beer.

3. *Fermentation.* The wort which is now mainly a solution of starch-sugar and gum, with several nitrogenous substances, the empyreumatic principles of the malt (if kiln-dried malt be employed), and the aromatic and bitter principle of the hop is then, when sufficiently cool, let down into the fermenting or gyle-tun. In large establishments, as in some of the London breweries, the size of the fermenting-tun is such that they contain from 1200 to 1500 barrels. The quantity of wort introduced at a time must, however, be considerably less than the capacity of the vessel, to allow room for the head of yeast, which rises during the process, and may, in some cases, rise to a third of that depth. In general, the fermentation proceeds more uniformly in large masses, because they are little influenced by vicissitudes of temperature. The place of fermentation ought also to have a uniform temperature, and is therefore often located under ground. For the theory of fermentation, by which sugar is converted into alcohol and carbonic acid, we refer to the article FERMENTATION. In beer, this conversion of sugar must only be partial, since it is required that beer should contain a certain quantity of it in solution. The amount of the remaining sugar is greater in proportion to the strength of the wort, since a certain quantity of alcohol already formed prevents the operation of the ferment on the remaining wort. The temperature exercises the greatest influence on the fermentation. The warmth of the wort, as it comes into the fermenting-tun, must be modified according to the air in the apartment. A temperature of from 55° to 60° of the liquor is generally most advantageous for the commencement, when that of the atmosphere is 55°. In winter, when the apartment is cold, the wort should not be cooled under 64° or 60°. In summer, on the contrary, when the temperature of the place rises to above 75°, the wort should be cooled down, if possible, to 55°, by passing it through cold water in a system of pipes. The higher the temperature of the wort, the sooner will the fermentation begin, and the less is it possible to regulate its progress. In some breweries a convoluted pipe is made to traverse or go round the sides of the tun, through which warm water is allowed to flow in winter and cold in summer, so as to regulate

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the temperature of the mass to the proper fermenting pitch.

When the wort is discharged into the fermenting tun it must receive its dose of yeast, which has been previously mixed with a quantity of the wort and left in a warm place till it has begun to ferment. This mixture, called *lobb*, is then to be put into the tun and stirred well through the mass. The yeast should be taken from similar beer. Its quantity must depend upon the temperature, strength, and quantity of the wort. In general, 1 gallon of yeast is sufficient to set 100 gallons of wort in complete fermentation. An excess of yeast is to be avoided, lest the fermentation should be too violent, and be finished in less than the proper period, from 4 to 8 days. More yeast is required in winter than summer, for at a temp. of 50° twice as much may be used as at 68°.

Six or eight hours after adding the yeast, the tun being meanwhile covered, the fermentation becomes active; a white, milky-looking froth appears, and spreads gradually over the whole surface, and forms a frothy elevation, the height of which increases with the progress of the fermentation, and gradually changes its color to a bright brown, owing to oxidation from the air. During this time there is a perpetual disengagement of carbonic acid gas, which escapes in small bubbles, rising to the top and carrying the precipitated particles of yeast with them to the surface of the liquid. The warmth of the fermenting liquid increases at the same time till the fermentation has come to its highest point. This increase of temperature may amount to from 9° to 14°, or more; but, in general, the fermentation is not allowed to proceed so far in the large fermenting-tun, for, after it is advanced to a certain point, the beer is *cleansed*; that is, drawn off into smaller fermenting-tuns or *stillions*, which are large barrels set on end, with large openings in their top, furnished with a sloping tray for discharging the yeast, which is thrown off into a wooden trough. These stillions communicate with each other, and with a larger tub, by means of which they are always kept full, so that the head of yeast may spontaneously flow over and keep the body of the liquor in the casks clean.

It must be observed that the quantity of yeast and the heat of the fermentation differ for every different quality of beer. During the fermentation, the sweet taste of the wort is continually diminished, while it, at the same time, assumes a refreshing flavor, and in proportion as the sugar is decomposed and the alcohol increases, the specific gravity of the liquor decreases, so that the progress of the fermentation may be ascertained by a hydrometer.

When the plan of *cleansing* casks is not employed, the yeast is removed from the surface of the fermenting-tun by a skimmer, and the clear beer beneath is then drawn off.

Ripening. When sufficiently fermented, the beer is let down into the close *store-tuns* in the cellar, where it may be kept at a uniform and low temperature. There, an obscure and slow fermentation goes on for a considerable time,

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which increases its spirituous strength and keeps up in it a constant impregnation of carbonic acid gas, so as to render it lively and agreeable to the taste. It is then either casked off for sale, or filled in bottles. In the latter case, the carbonic acid which still continues to generate, cannot escape, and remains dissolved in the beer, and causes, by its escape, the frothing of the beer, on the opening of the bottles.

Prop. The main ingredients of beer, are, besides water: alcohol, the bitter principle (lupuline or lupulite), and aromatic volatile oil of hops, gum, sugar, empyreumatic principle from the malt, when kiln-dried, small quantities of nitrogenized substances (gluten), brown extractive, a small portion of tannin (hops), and carbonic acid. The sugar, gum, and other solid ingredients, which remain on evaporation, are generally comprised under the name of *malt-extract*; on its quantity depends the body of the beer, while by its strength is generally meant its content of alcohol. Its intoxicating property depends, however, a great deal on the bitter and narcotic substance of the hops. From wine, it differs not only in this respect, and in its smaller proportions of alcohol, but also in containing a much larger quantity of nutritive matter.

The following table shows the quantity of alcohol in some beers.

	Proportion of Spirit of sp. gr. 0.825.	
	Per ct. by meas.	Per ct. by wt.
Ale, Burton,.....	8.88	7.326
average,.....	6.87	5.667
Brown stout,.....	6.80	5.610
London porter (average),	4.20	3.465
Small beer,.....	1.28	1.056

The difference in the different varieties of beer depends upon a difference in the materials employed, or in the process and management of the brewing. In regard to the materials, beers differ according to the different kinds of malt employed, and its proportion to the quantity of hops and of water. To the class of *table* or *small beers*, all those may be referred, whose specific gravity does not exceed 1.025, and which contain about 5 per cent. of malt extract. Beers of middling strength have generally a spec. grav. of from 1.025 to 1.040. Some of the Scotch and English ales form some of the strongest and heaviest kinds of beer.

The following table indicates the spec. grav. of some of the English beers.

	Spec. grav.
Ale, Burton, 1st sort,.....	1.111 to 1.120
“ 2d “	1.097 to 1.111
“ 3d “	1.077 to 1.092
Common,.....	1.070 to 1.073
“	1.058
Porter, common sort,.....	1.050
“ double.....	1.055
Brown stout,.....	1.064
“ best,.....	1.072
Beer, common small,.....	1.014
“ good table,.....	1.033 to 1.039

The strength and quality of some of the German beers may be seen from the annexed table.

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	Water.	Per cent. by weight.			Authority.
		Malt extract.	Alcohol.	Carb. acid.	
Augustine double beer, Munich, Bavaria, . . .	88-36	8-0	3-6	0-14	Kaiser.
Salvator beer, Munich,	87-62	8-0	4-2	0-18	"
Bock from the Royal Brewery in Munich, . . .	88-64	7-2	4-0	0-16	"
Small beer (Schenk bier) from a country brewery, Bavaria,	92-94	4-0	2-9	0-16	"
Bock, Brunswick, made by the Munich process, .	88-50	6-50	5-00	not determ.	Balhorn.
Table beer, Brunswick, made by the Bavarian process,	91-10	5-4	3-50	"	Otto.
Brunswick small beer, sweet,	84-70	14-0	1-30	"	"
Brunswick Mumme,	59-2	39-0	1-8	0-1	Kaiser.

The color of the beer depends upon the color of the malt and the duration of the boil in the copper. Pale ale is made from steam or sun-dried malt, and the young shoots of the hop; the deep yellow ale from a mixture of pale yellow and brown malt, and the dark brown beer from well kilned and partly carbonized or parched malt, mixed with a good deal of the pale, to give body. The longer and more strongly the malt has been heated in the kiln, the smaller is the quantity of extract it yields, *ceteris paribus*. Porter is generally prepared from high-dried or rather charred malt, which, therefore, has had much of its saccharine matter destroyed by heat. Hence its deep color, and the absence of any sweet taste, while ale has a sweetish taste, and contains a much larger quantity of saccharine matter.

The greater or less rapidity of the temperature, and the manner in which the worts are made to ferment, have a remarkable influence upon the quality of the beer, especially in reference to its fitness for keeping. Under the article FERMENTATION it will be shown that two kinds of fermentation may be distinguished, the upper and the lower or bottom fermentation. The former is a much more active fermentation, by which, according to Liebig, the gluten is only partly oxidized, at the expense of the oxygen of a portion of the sugar, while a great portion remains dissolved in the liquor, and by its subsequent oxidation is apt to transfer oxygen to the alcohol and render it sour, unless it be kept at a very low temperature. This is still more the case, if during a too violent fermentation the temperature rises too high, and especially if the air be not perfectly excluded, and a considerable quantity of acetic acid be formed, by which an additional quantity of glutinous matter is dissolved, and it thus is not only rendered apt to spoil from the slightest causes, but loses also its limpidity and assumes a disagreeable taste, or becomes *yeast bitten*. By the lower fermentation, on the contrary, the conversion of the sugar into alcohol is performed very slowly and without any considerable rise of temperature, so that the gluten is completely oxidized and precipitated by the oxygen of the air and without conversion of any alcohol into acetic acid, so that the resulting beer, as is the case with Bavarian beer (see below), is not liable to become sour, or to undergo the acetous fermentation. Where this is not the case, the tendency to become sour is generally remedied by a large addition of hops, and a greater proportion of malt, by which the beer becomes more narcotic and intoxicating, and less agreeable to the taste, and such beer is then often considered as drugged.

A main feature of good beer is its fine color and transparency, the production of which, therefore, is an object of great interest to the brewer. Attempts to clarify the beer in the casks seldom fail to do it harm. The only thing that can be used with advantage for *fining* a muddy or foul beer, is isinglass. For porter, as commonly brewed, it is frequently had recourse to. (See under CLARIFICATION.) To ascertain whether the beer is in a state fit for fining, put some of it in a long cylindrical glass vessel, and add to it a teaspoonful of the fining, and shake it well with it, closing the mouth of the vessel with the finger or the palm of the hand. Its aptitude to become bright will then soon be evident, by the mixture first becoming curdy, and then on repose separating, the finings generally rising to the top and leaving the liquid below clear and brilliant.

We shall now add a few observations on the brewing of some varieties of beer, which present peculiarities in the method of their manufacture.

Scotch Ale. This beverage is characterized by its pale amber color and its mild balsamic flavor. The bitterness of the hop is so mel-
lowed with the malt as not to predominate. The ale of Prestonpans is, in fact, the best substitute for wine which barley has hitherto produced. The low temperature at which the Scotch brewer pitches his fermenting-tun restricts his labors to the colder months of the year. He does nothing during four of the summer-months. He is extremely nice in selecting his malt and hops, the former being made from the best English barley, and the latter being the growth of Farnham and East Kent; the yeast is also carefully looked after. (*Ure*.)

Only one mash is made by the Scotch ale-brewer, and that pretty strong; the mash-liquor being heated as high as 180°. After mashing for about half an hour, or until every particle of the wort is thoroughly drenched, the tun is covered and the mixture left to infuse about three hours. It is then drained off into the wort-copper, and the malt exhausted by eight or ten successive sprinklings of liquor (hot water) of 180° over the surface of the malt, which are termed, in the vernacular tongue, sparges, by which the water is dashed on a perforated circular board, suspended horizontally over the mash-tun, whence it descends like a shower upon the whole of the goods (malt). The percolating wort is allowed to flow off by three or more small stopcocks around the circumference of the mash-tun, to insure the equal diffusion of the liquor.

The first sparge being run off in the course of 20 minutes, another similar one is affused, and thus in succession, till the whole of the drainage, when mixed with the first mash-wort, constitutes the density adapted to the quality of the ale. Thus the strongest worts are prepared, and the malt may then be still further exhausted for an inferior beer. The last sparges are made 5° to 6° cooler than the first. By this system the waterings percolate through the malt on the mash-tun bottom from above, and extract the remaining wort much more perfectly than could be done by a subsequent mashing, so that by this simple method a large quantity of wort may be obtained of a much higher specific gravity. The only serious objection to the sparging system is the loss of time by the successive drainages. A mash-tun with a steam jacket would improve the sparging system, as it would keep up a uniform temperature in the goods without requiring them to be sparged with very hot liquor.

The quantity of hops seldom exceeds four pounds to the quarter of malt. The manner of boiling the wort is the same as that above described, but that of conducting the fermentation is peculiar. The heat is pitched at 50° , and the fermentation continues from a fortnight to three weeks. Thus, if three brewings were made in the week, seven or eight working tuns would be in constant action. The yeast is added in the fermenting-tun in the proportion of one gallon to 240 gallons of wort; but no more yeast is used than is indispensable; if a little more be needed, it is made effective by rousing up the tuns twice a day from the bottom.

When the progress of the attenuation becomes so slack as not to exceed half a pound in the day, it is prudent to cleanse. When the ale is cleansed, the head which has not been disturbed for some days is allowed to float on the surface till the whole of the pure liquid is drawn off into the casks. The Scotch do not skim their tuns as the London ale-brewers commonly do. The Scotch ale, when so cleansed, does not require to be set upon close stillions, as it throws off little or no yeast, because the fermentation was nearly finished in the tun. The strength of the best Scotch ale ranges between 32 and 44 pounds to the barrel, or has a specific gravity of from 1.088 to 1.122, according to the price at which it is sold.

Bavarian beer. In the Bavarian process, the malt is first mixed with water of ordinary temperature. For 1 pt. of malt about 3.9 pts. of water are employed. The whole is then allowed to rest for 6 to 8 hours, after which the mashing is begun by mixing the mass with 3 pts. of boiling water added gradually during continual agitation, by which its temperature is raised to 106° . The thick part of the mash is then transferred to the copper, and heated to boiling during continual agitation, and after an hour's boiling, again returned to the mash-tun and mixed thoroughly with its liquid contents, by which the temperature in the mash-tun is raised to 133° . The thick part of the mash is then once more transferred and boiled for an

hour in the copper, and returned in the same way to the mash-tun, by which the temperature is raised to 154° . The fluid part of the mash is next transferred by bailing or draining into the copper, boiled for a quarter of an hour, and then poured back on the mash in the tun and mixed thoroughly with it. The temperature is hereby raised to from 167° to 180° . After agitation for a quarter of an hour, the mash is left at rest for 1 or $1\frac{1}{2}$ hours, after which the clear wort is drawn off and treated in the usual manner.

It will be seen that, by this method, the mashing is performed in the mash-tun at a temperature of from 133° to 180° , and the mass treated at a still higher temperature in the copper. At a temperature between 140° and 167° , starch is principally converted into sugar by diastase, while at still higher temperature, into gum, which latter, therefore, must be formed in considerable quantity by this process, the boiling of the liquid destroying the effect of the diastase in the solution, and preventing it from converting the gum subsequently into sugar. The albuminous matters are also coagulated by boiling, and clarify, by their precipitation, the wort, while the husk becomes much shrunk, and therefore retains but little of the wort, so that the latter drains off easily and more completely, and the second wort is therefore only of small avail. Notwithstanding the longer duration of the mashing, the mass is less apt to become sour, both on account of the temperature being above the degree favorable for this change, and more especially all albuminous matter, by which the conversion of starch, sugar, and gum, into lactic acid is effected, is precipitated by the boiling.

The fermentation of the Bavarian beer is also peculiar, being performed very slowly, and at a very low temperature (45° to 50°), and mostly by the so-called lower or bottom fermentation (see above), by which little or no acetic acid is formed, and all the gluten and other nitrogenized substances so completely precipitated that, from the perfect absence of these substances, which, by their oxidation, form ferment for the acetic fermentation, Bavarian beer is incapable of undergoing the acetous fermentation even by free exposure to the air.

A number of other amylaceous substances, besides barley, are often employed as additions in the preparation of inferior qualities of beer, such as potatoes, beans, turnips, beets, carrots, &c. Thus, Strasburg ale is mainly manufactured from mashed potatoes mixed with from $\frac{1}{20}$ to $\frac{1}{10}$ of their weight of ground-barley malt. This is mixed with some water, and exposed in a water-bath to a heat of 160° , whereby it is partly converted into saccharine matter, and may then be boiled with hops, cooled, and fermented into beer.

Maize or Indian corn has also been employed to make beer, but its malting is somewhat difficult (see under *MALT*).

The name of beer is also, but improperly, given to many beverages made from saccharine liquors, and advanced more or less into the vinous fermentation and flavored with pe-

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culiar substances, such as Spruce and Ginger Beer, &c. (which see).

Use. That beer is nutritive, and, when used in moderation, salubrious, can scarcely be doubted. It proves a refreshing drink and an agreeable and valuable stimulus and support to those who have to undergo much bodily fatigue. (*Pereira.*) The hop operates as a tonic, and assists digestion. With dyspeptics, beer as well as other fermented liquors are very apt to disagree, and should therefore be avoided. It is also objectionable to those liable to lithic acid deposits, and for plethoric persons, who have a tendency to apoplexy. Ale containing a much larger proportion of saccharine matter (see above) is more objectionable for diabetic and dyspeptic patients than porter.

BEER, EXAMINATION OF. The examination of beer has principally for its object to estimate the quantity of its ordinary ingredients, and to discover the admixture of foreign, accidental, or designed substances or adulterations.

Beer ought to be perfectly clear; turbidity indicates either that the fermentation has not been complete, or that the formation of acetic acid has begun. The greater or less color indicates the degree of heat to which the malt has been exposed and the length of time the wort has been boiled. The frothing, when poured out, depends on the variety of the beer and the manner of keeping it in casks or in bottles. Beer containing but little carbonic acid has a flat taste. The smell of beer depends on the hops, the malt, the alcohol, and the carbonic acid. By addition of common salt, and gentle heating, the smell of the hops is made more apparent, and may be better judged of in regard to its quantity and quality. The taste will still better decide as to the quantity and quality of the hops employed, and the body of the beer.

In examinations of beer, the amounts of the following ingredients are generally ascertained: *malt extract* (see the former part of this article), *alcohol*, *water*, and *carbonic acid*. The quantity of the last does not usually amount to more than 0.1 or 0.2 per cent.; its exact proportion is therefore often neglected, especially as its relative quantity is apparent from the greater or less frothing. In general, a quantitative estimation is therefore desired only of the malt extract and the alcohol, from which, then, the quantity of water results by deduction. This, in combination with its effect on the senses, will give a good idea of the quality of the beer.

In order to ascertain the amount of *malt extract*, a weighed quantity of beer is evaporated cautiously and the residue weighed. It is, however, difficult to obtain it perfectly dry, as the last portion of water requires a rather high temperature for its expulsion, which might cause it to commence decomposing.

The amount of *alcohol* is ascertained by distilling a weighed portion of beer in a retort, and, from the weight and specific gravity of the distilled liquid, determining its content of alcohol (see under **ALCOHOMETRY**).

It has already been mentioned above that

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solutions of malt extract and of sugar of the same spec. grav. contain an equal amount of solid matter. If, therefore, a weighed quantity of beer be heated until all carbonic acid and alcohol has been expelled, and the remaining portion again diluted with water until it has attained its previous weight, the amount of malt extract may be determined from its specific gravity. If, moreover, the specific gravity of the beer be previously ascertained, the amount of alcohol may be estimated from the difference in the two specific gravities. The contained carbonic acid affects the specific gravity but very slightly, and the greater part may be removed by gently heating and shaking the liquid. Let the specific gravity of a beer be found to be 1.025, and after the expulsion of the carbonic acid and the alcohol by boiling, and subsequent dilution with water to the original weight of the beer, to be 1.032. The latter specific gravity corresponds to 8 per cent. of malt extract (see table under **BEER**, page 298). The difference between the specific gravities 1.032 and 1.025 is 0.007, which therefore will constitute the difference in specific gravity between pure water and dilute spirit containing the same amount of alcohol as the beer, or having the specific gravity of 0.993 (1.000 — 0.007), which corresponds to 4 per cent. alcohol by weight, or 5 per cent. by volume, as the following table will show, which we add for convenience:

Per ct. of alcohol.	Spec. grav. of spirit at 63° 5° Fah.	
	Per ct. by weight.	Per ct. by vol.
12	0.9806	0.9834
11	0.9817	0.9846
10	0.9830	0.9859
9	0.9844	0.9873
8	0.9860	0.9887
7	0.9878	0.9901
6	0.9897	0.9915
5	0.9914	0.9929
4	0.9931	0.9943
3	0.9948	0.9957
2	0.9965	0.9971
1	0.9982	0.9985

It may, however, be remarked that this method, in order to yield satisfactory results, requires the specific gravities to be taken with great accuracy, either by a delicate hydrometer or a spec. grav. bottle, and with due regard to temperature.

The amount of *carbonic acid* may be ascertained by heating a weighed quantity of beer, and collecting the expelled carbonic acid, with the necessary precautions, in a pneumatic apparatus, determining its quantity by volume, from which its weight may then be calculated. Another method consists in introducing a weighed quantity of the beer into a bottle or flask, in the orifice of which is fitted, by means of a perforated cork, a tube containing chloride of calcium (such as *b c*, *Fig. 26*, page 188), and heating very slowly the contents of the flask almost to ebullition, by which the carbonic acid is expelled, while the vapors of water and alcohol are retained by the chloride of calcium. The loss in weight of the whole apparatus

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before and after the experiment then indicates the amount of carbonic acid.

If desired, the sugar and gum of the malt extract may be separated by moderately strong alcohol. The extract is first made by water into a thin syrup, and then alcohol added as long as gum precipitates, which by repetition of the same treatment may be freed almost perfectly from sugar. The quantity of sugar may also be determined by the quantity of carbonic acid which it yields by fermentation (see under *SUGAR*). A content in the gum of unaltered starch may be ascertained by a solution of iodine.

The presence of foreign substances, either accidental or designed, are often proved with difficulty by chemical tests. Among such adulterations may be mentioned sulphate of iron, alum, and salt, added under the name of *beer heading*, to impart a frothing property to it. Molasses and extract of gentian are added with the same view. Capsicum, grains of paradise, ginger-roots, coriander-seed, and orange peel, are also employed to give pungency and flavor to weak or bad beer. The following is a list of substances seized in London as intended for adulterations (*Ure*): cocculus indicus multum (an extract of the cocculus), coloring, honey, hartshorn-shavings, Spanish juice, orange powder, ginger, grains of paradise, quassia, liquorice, caraway seed, copperas, capsicum, &c. Sulphuric acid is frequently added to bring beer forward, giving new beer instantly the taste of what is 18 months old. Quassia, aloes, cocculus indicus, and other bitter or poisonous substances are best discovered by their bitter taste or effect on the system. Care should however be taken not to do injustice imprudently to brewers, as sometimes large quantities of hops are added in order to make the beer keep, and then impart a very bitter taste and a narcotic effect to it. Dobereiner prescribes to test the malt extract for narcotic substances by the dilatation of the pupil produced when applied to the eyes of a cat.

The addition of distilled liquors may be suspected from a great content of alcohol and small amount of malt extract. It may also be recognised by its peculiar smell, when separated from the beer by distillation. Acetic acid is discovered by the sour taste and acid reaction of the distillate. Presence of inorganic substances are detected in the ashes after incineration of the malt extract; a small portion of salt is however often added, and can hardly be considered as an adulteration. (See Zennoch on the examination of beers, Munich, 1834.)

BEET. *Tech. Ger.* Runkelrübe; *Fr.* Betterave. The root of the *Beta alba*, although so largely employed in Europe in the manufacture of sugar, has not received a very minute chemical investigation. The following substances have been found in the white Silesian beet, and nearly in the proportions indicated.

BENZOIN.

Water, on an average	84.0
Crystallizable sugar (average).....	10.0
Vegetable fibre.....	2.0
Albumen and nitrogenous substance ...	1.5
Pectin, malic acid, coloring and aromatic substances, fixed oil, bitter essential oil, chlorophyll, asparagin, oxalate of lime, phosphates of lime and magnesia, malate and phosphate of ammonia, sulphate, nitrate and oxalate of potassa, chlorides of potassium and sodium, sulphur, silica and oxide of iron	2.5
	100.00

The quantity of sugar varies from 8—12 pr. ct., but in the progress of manufacture a portion of it is rendered uncrystallizable. Although a large yield might be expected from the above analysis, the quantity of juice obtained on an average is about 66 pr. ct. with 34 pr. ct. pulp, and the amount of sugar about 5 pr. ct. of the weight of the root.

BELLADONNA. *Bot.* A plant of the Solanaceæ, *Atropa Belladonna*, (Common Dwale; Deadly Nightshade), the leaves of which yielded to Brandes—

Permalate of atropin	1.51
Pseudotoxin, with some salts.....	16.05
Phytocolla	6.90
Wax	0.70
Resinous chlorophyll.....	5.84
Albumen	10.70
Gum	8.33
Starch	1.25
Fibre	13.70
Salts of sulphuric, nitric, phosphoric, acetic, oxalic and muriatic acids, with potassa, ammonia, lime and magnesia	7.47
Water	25.50
Loss.....	2.05
	100.00

The ashes gave a trace of oxide of copper.

The pseudotoxin and phytocolla are nitrogenous substances, the former soluble, and the latter insoluble in alcohol. Lübeckind has described another alkaloid, which he termed Belladonnin, but which does not probably exist. See *ATROPIN*.

BELL-METAL. *Tech.* See *BRONZE*.

BENZOIN. *Phar. Perfum. Syn.* Benjamin. A gum-resin obtained from the *Styrax Benzoin* in Sumatra, Bornea, Java and Siam. The bark of the 6 year old tree is slit, to allow a liquid to flow out, which concretes by exposure to sun and air into a semi-hard mass. The finer kinds consist of whitish or reddish yellow tears agglutinated by a brown mass, called white or amygdaloidal; the inferior is brown, with but little white. Sp. gr. = 1.063 1.092, brittle, pulverizable, with conchoidal fracture and fatty lustre, of an agreeable odor, fuses at a gentle heat, is soluble in alcohol and ether, leaving a residue in the latter, scarcely soluble in fixed or volatile oils. Of the following analyses, 1. is by Bucholz, 2. by John, 3, 4, and 5. by Stoltze, 6. by Kopp.

BENZOIN.

	1.	2.	3. White.	4. Amygdal.	5. Brown.	6.
Benzoic acid	12.5	12.0	19.80	19.42	19.70	14.0
Yellow resin	} 83.3	} 84.5	79.83	27.10	8.80	α . 52.0
Brown resin			0.25	50.53	69.73	β . 25.0
Aromatic extractive	0.5	0.5	—	0.25	0.15	γ . 3.0
Woody matter, &c.	2.0	2.0	—	2.60	1.45	δ . 0.8
Water and loss	—	0.25	0.12	0.10	0.17	Impurities 5.2
	100	100	100	100	100	100

Traces of volatile oil were found; Bucholz gives in addition to the above (1) 1.7 pr. ct. of a balsamic substance; John gives 0.75 of 1 pr. ct. of salts. The resin and acid constitute nearly the whole mass.

Resin. Stoltze makes out two resins, a yellow soluble in ether, a brown insoluble in ether. Unverdorben finds 3 resins by boiling benzoïn with carbonate of potassa, which dissolves the acid, and the gamma-resin leaving the other two, of which alpha-resin is soluble in ether, beta-resin insoluble. α soluble in alcohol, ether, potassa, not in petroleum or ammonia. Its metallic and earthy compounds are insol. in ether. β is brownish when washed and dried, insoluble in ether, essent. oils, ammonia, soluble in alcohol and potassa. The alkaline solutions of α and β precipitated by an acid and exposed still moist to the air, change into γ ; they both yield by distillation a little empyreumatic oil, which changes in the air into benzoic acid. γ is obtained by precipitating the solution in carbonate of potassa by an acid, and washing out benzoic acid with boiling water. The resin makes 3 pr. ct. of the benzoïn; it is dark brown, soluble in alcohol, slightly in ether and essent. oils, not in petroleum; it is slightly acid, not decomposing acetate of copper, but precipitating acetate of lead, and dissolving slowly in carbonate of potassa.

According to Kopp's researches, benzoïn resin subjected to distillation is resolved into carbon, carburetted hydrogen, water, phenole and benzoic acid. Thus 4 eq. of the resin ($C_{20}H_{11}O_4$) = $C_{80}H_{44}O_{16}$ produce

3 eq. benzoic acid... $C_{42}H_{18}O_{12}$
 1 eq. phenole..... $C_{12}H_6O_2$
 8 carbon + 2 water. (C_8)(H_2O_2)
 18 olefiant gas..... $C_{18}H_{18}$

4 eq. benzoïn resin... $C_{80}H_{44}O_{16}$

On treating benzoïn with nitric acid, oil of bitter almonds and benzoic acid pass over, and the residue contain carbazotic and benzoëresinic acids, which are converted into salts of potassa and separated by crystallization.

Benzoëresinic Acid is an amorphous yellowish white powder, of pungent taste, very soluble in alcohol and ether, dissolved by sulphuric, muriatic, and nitric acids, and precipitated unaltered by water; fuses at 248° , subliming with partial decomposition at a higher temperature. The alkaline salts are yellow and amorphous; the salts of potassa may be obtained crystalline; this salt precipitates metallic salts, those of lead sulphur-yellow, of silver brownish yellow, of copper bright green, of alumina pure yellow, of peroxide of iron yellowish white, of

BENZILE.

protoxide of iron yellowish green. *Chem. Gaz.* February, 1844.

Taking these together as resin of benzoïn, it is soluble in alcohol, acetic, sulphuric, and nitric acids, in caustic alkali; in sulphuric, with a deep red color, from which water throws down red scales; in nitric it is violently dissolved and decomposed, both acids producing finally artificial tannin.

Use. Employed to a limited extent in medicine, and in fumigations from the agreeable odor which it exhales.

The following formulæ are deduced from the late analyses of the 3 resins by Van der Vliet and Mulder, according to their calculations:

γ $C_{30}H_{20}O_5$
 β $C_{40}H_{22}O_9$
 α $C_{70}H_{42}O_{14}$

But Berzelius shows that the following formulæ correspond rather better to the analyses.

γ $C_{30}H_{21}O_5$
 β $C_{40}H_{21}O_9$
 α $C_{70}H_{42}O_{14}$

In either case it would appear that α is not a single organic oxide, but a compound of 1 eq. β + 1 eq. γ , as shown by the sum of β and γ = α , and hence benzoïn is a chemical compound of β + γ . The 9 eq. of oxygen in β seem to indicate that it may consist of two organic oxides. *Berz. Jahresb.* xx. 390, from *Bullet. d. Sc. Phys. et. nat. en Neerlande*, i. 208.

In Jonston's experiments with benzoïn, oxide of lead decomposed it into two resins, with the formulæ $C_{40}H_{22}O_9$, and $C_{40}H_{26}O_{10}$, the former of which agrees with resin β above. Benzoïn boiled with lime, the lime compound decomposed, and its resin analyzed, gave $C_{40}H_{24}O_9$; the resin from potassa gave $C_{40}H_{22}O_9$; benzoïn itself gave, after purification with carbonate of potassa, muriatic and acetic acids, and water, $C_{40}H_{24}O_8$. From the solution after boiling with lime and potassa the dissolved resin, precipitated and purified, gave $C_{40}H_{30}O_7$. *Phil. Trans.* 1839-40.

BENZILE. *Chem. Syn.* Benzule or Benzoyl. (*Laurent*). *Prep.* Chlorine gas is passed over melted benzoïn as long as chlorohydric acid escapes. The crystalline mass which remains after cooling is dissolved in hot alcohol, which on cooling deposits crystals of pure benzile. It is sometimes found along with benzoïn in the residue of the distillation of raw oil of bitter almonds with hydrate of lime and protochloride of iron; and may easily be separated from that substance by crystallization. 2. A simpler method is to add 2 parts of pure nitric acid to 1 part of benzoïn, and to expose this mixture to a gentle heat; violent action ensues from the escape of nitrous acid, and the benzile appears as a colourless oil on the surface of the liquid. (*Zinin*.)

Prop. Large sulphur-yellow, translucent, regular six-sided prisms, belonging to the hexagonal system; tasteless, inodorous; melting at about 200° ; insoluble in water, soluble in alcohol and ether; of the hardness of sugar, crackling between the teeth; volatile without decomposition; inflammable, burning with a red smoky flame; soluble in oil of vitriol, from which it is precipitated by water; insoluble in an aqueous solution of potassa with which it may be boiled without decomposition; but soluble with decomposition in an alcoholic solution of potassa, to which it gives a violet-blue color, while it passes into benzoic acid.

Formula of benzile, $C_{14}H_5O_2$. It has, therefore, the composition of the hypothetical radical benzyl.

Hydrocyanate of Benzile. (Zinin.) When a hot solution of benzile in alcohol is mixed with an equal bulk of anhydrous prussic acid, large rhombic colorless crystals of this substance are formed. They are insoluble in water and muriatic acid, and decomposed by ammonia and nitric acid into benzile and prussic acid. Its form. is $C_{14}H_5O_2 + HCN = C_{16}H_6NO_2$; hence it consists of 1 atom of benzile, and 1 atom of prussic acid.

Benzilic Acid. *Prep.* (Liebig.) By boiling benzoin or benzile, with a concentrated alcoholic solution of potassa, in which it dissolves easily with a violet-blue color, which disappears by continued boiling. The alkaline solution is added as long as it causes any blue color after the previous portion has been decolorized by boiling, and the solution is then carefully neutralized by chlorohydric acid, by which means a resinous matter is separated. To the filtered solution is added an excess of hydrochloric acid, and on cooling the benzoic acid crystallizes.

Prop. Benzoic acid forms colorless, transparent, brilliant, rhombic crystals, sparingly soluble in cold water, in hot more easily; very soluble in alcohol and ether; fusible at 230° , not volatile; heated more strongly, it yields benzoic acid which sublimes, a violet-colored vapor, which condenses to a carmine-red oily liquid and a residue of carbon; it burns with a smoky flame. If brought in contact with cold oil of vitriol, a lively carmine-red color is developed, which disappears by dilution and returns by concentration.

If to the elements of 2 eq. benzile those of 2 eq. water be added, we have the composition of benzoic acid; in which, however, one atom of water is basic, as it can be replaced by metallic oxides. Formula, $C_{22}H_{11}O_5 + HO$.

The quantity of the resinous matter above-mentioned formed with it is always trifling, and most probably is not essentially connected with it. The oxygen of the atmosphere seems to have some share in the production of benzoic acid from benzoin; but these reactions have not yet been sufficiently investigated. The red oil obtained as above is insoluble in water, soluble in alcohol; its color is destroyed by potassa, ammonia and nitric acid, but not altered by sulphuric or muriatic acid.

Salts. The potassa salt crystallizes in large transparent tables, readily soluble in alcohol and water, not in ether, fuses at and congeals

again on cooling; by distillation it yields a colorless volatile oil resembling naphthalin in odor. The silver salt is $C_{28}H_{11}O_5AgO$, and forms a white crystalline powder, insoluble in water, slightly in hot; heated to 212° it loses nothing in weight, but changes to blue, and at a higher heat evolving violet vapors. The lead salt is a white crystalline anhydrous powder, slightly soluble in water, fusing to a red liquid above 212° .

BENZIMIDE. (Laurent.) An ingredient of the raw oil of bitter almonds, from which it separates under certain circumstances. It forms white, inodorous, pearly needles and lamellæ, very light and flocky; insoluble in water, very sparingly soluble in alcohol and ether, rather more so in pyroxylic spirit. It melts at about 300° ; is inflammable, burns with a red, smoky flame; and is dissolved and decomposed by nitric, hydrochloric, and sulphuric acids; the latter of which is colored by it dark indigo-blue, or green, if moisture be present. According to Laurent, it is resolved by acids into ammonia and benzoic acid; but, for want of material, his experiments are not to be considered decisive. Formula $C_{22}H_{11}O_4N$. Nothing is known of the way in which it is formed; but if the formula be correct, it may be considered as anhydrous benzoate of ammonia, minus 2 eq. water.

BENZOIC ACID. *Phar. Chem. Syn.* Flow-ers of Benzoin or Benjamin. *Ger.* Benzoesäure. It exists in benzoin, many balsams (Peru, Tolu, Styrax, &c.), in urine, and is formed by the oxidation and decomposition of several benzylic compounds, oil of bitter almonds, hippuric acid, amygdalin, &c., by the action of potassa on oil of cinnamon and other essential oils, &c. &c.

Prep. 1. Gum benzoin, in the form of a coarse powder, either alone or mixed with an equal weight of sand, is spread upon the bottom of a round vessel of cast or sheet iron, 8 or 9 inches diameter, the sides of which should not be more than 2 inches high. A sheet of dry bibulous paper is stretched tightly over the opening, and fastened to the sides of the vessel by a little paste. A hat made of thick paper, and of the common form of a man's hat, is made to cover the whole, and tightly tied and pasted to the sides of the vessel. The vessel is now placed upon a sand bath which is heated for 3—4 hours, and cooled. The vapors of the sublimed benzoic acid pass readily through the pores of the bibulous paper, which retains the oil, and are deposited in crystals upon the hat; the crystals are prevented from falling back into the iron vessel by the paper which closes its opening; the yield is 4 per cent. (*Mohr.*) 2. Equal parts of finely powdered gum benzoin and hydrate of lime are most intimately mixed, and then boiled for several hours in 40 parts of water; the filtered liquid must then be evaporated to one-fifth its volume, and treated with hydrochloric acid, when the benzoic acid will crystallize as the solution cools. If less lime be taken, or if a perfect admixture be neglected, the whole will bake into a solid mass in the boiling water; in this case, the hard fragments, after the whole has cooled, must be again

BENZOIC ACID.

mixed with hydrate of lime. The acid obtained by 1 and 2 is purified either by a second sublimation, or being boiled in nitric acid. 3. Hippuric acid is boiled for one quarter of an hour in nitric acid of sp. gr. 1.42, after which water is added, and the solution allowed to crystallize.

4. Pulverized benzoïn resin is dissolved, with the assistance of heat, in about an equal volume of highly rectified alcohol, and the solution mixed while hot, but gradually, with so much fuming muriatic acid that the resin begins to be precipitated. The mass is then submitted to distillation. The benzoic acid passes over in the form of benzoic ether. The distillation is carried on as long as the consistence of the mass admits; when it becomes too thick, it is allowed to cool a little, hot water added to it, and again distilled as long as any ether passes over. The water remaining in the retort is, when clear, poured off boiling-hot from the resin; on cooling it deposits benzoic acid, probably derived from the benzoic ether.

The product obtained is digested with caustic potassa until the whole of the ether is decomposed, finally heated to boiling, and saturated with muriatic acid, when the benzoic acid separates in crystals on cooling.

It appears that the entire amount of benzoic acid of the resin is obtained in this manner; and it may be observed, with reference to the pharmaceutical application, that the acid so prepared possesses entirely the odor of the sublimed acid. Whether the stated proportions of resin, muriatic acid, and alcohol are the most advantageous, cannot be affirmed at present. (*Wöhler in An. der Ch. u. Phar.* Feb. 1844.)

Prop. Benzoic acid crystallizes in soft white scales, which are flexible, transparent, and of a pearly lustre; or in hexagonal needles. When pure it is inodorous, but if gently warmed it smells like gum benzoïn; it usually has a faint aromatic odor; it has a slightly biting but sweetish taste, produces a burning sensation in the throat, reddens litmus feebly, fuses at 250°, sublimes at 300° (an appearance of light is frequently observed in the dark), boils at 462°, yielding a vapor of spec. grav. 4.27, burns with a white smoky flame; not changed by being boiled with dilute nitric acid, but by fuming nitric acid it is converted into a yellow resinous substance of a strongly bitter taste. It is dissolved by concentrated sulphuric acid, but falls upon the addition of water. It is soluble in 200 parts of cold water at 59° and 25 parts of boiling water; by boiling or evaporating its solution, a portion of the acid volatilizes with the aqueous vapor; very soluble in alcohol, soluble in ether, in fixed and essential oils.

Composition. The anhydrous silver-salt gave to Liebig and Wöhler the following composition of the anhydrous acid.

	Analysis.	Equivalent:		Calculated.
Carbon	74.378	14	84	74.70
Hydrogen ..	4.567	5	5	4.36
Oxygen . . .	21.055	3	24	20.94
	100		113	100

BENZOATES.

Its formula is $C_{14}H_5O_3$, and its symbol BzO , form. of the crystallized acid, $BzO + HO$, (eq. 122).

Uses. It was formerly much more employed in medicine than at present; when taken internally, it passes out through the urine in a short time, converted into hippuric acid. It is farther used in making the benzoates, several compounds of the benzylic series, &c.

BENZOATES. The combination of benzoic acid with the metallic oxides is usually attended with the separation of the water of the hydrate; the benzoates are generally soluble in water and absolute alcohol; the soluble salts have a strong biting saline taste, and are decomposed by most other acids with the separation of benzoic acid; the same change occurs with the insoluble salts, when the acid which is added forms a soluble salt with the metallic oxide. According to Lecanu and Serbat, many of the benzoates, which are insoluble in water, are taken up by hot solutions of the acetate of potassa and soda, and of nitrate of soda; they are insoluble, on the contrary, in solutions of nitre, and of the sulphate of potassa and soda. The benzoates of the alkalies are decomposed by the destructive distillation into carbonates, and a variety of new products. Exposed to a red heat with an excess of hydrate of lime, the acid is decomposed into benzole and carbonic acid, which unites with the lime.

Benzoate of Potassa. Ger. Benzoësaures Kali. Crystallizes with difficulty in fine, feathery needles; formula $KO, BzO + HO$. With an excess of acid is formed a crystallized salt, requiring 10 parts of water for solution. *B. of Soda* crystallizes with difficulty in efflorescing needles, difficultly soluble in alcohol. The salt of lithia dries to a deliquescent mass. *B. of Ammonia*, NH_4O, BzO ; is prepared by nearly saturating warm and strong caustic ammonia with benzoic acid and cooling; it deposits in feathery crystals, very soluble in water, soluble in absolute alcohol, deliquescent in moist air, losing ammonia in drying and becoming the acid salt. The acid salt, by spontaneous evaporation of the neutral, with loss of ammonia, forms large regular crystals.

By distillation benzoate of ammonia yields *Benzonitril*. It is a colorless oil, of a strong and agreeable odor closely resembling vol. oil of bitter almonds, of a biting taste, soluble in 100 water at 212°, in every proportion in alcohol and ether; spec. grav. at 59° = 1.0073; begins to boil at 374°, its constant boiling point being 375.8°; burns with a white smoky flame. Form. $C_{14}H_5N$. It is therefore isomeric with Laurent's nitrobenzyl. Its formation from the benzoate is thus shown, $C_{14}H_5O_3 + NH_3 = C_{14}H_5N + 3HO$; in which respect it seems to be analogous to the formation of cyanohydric acid from formiate of ammonia, $C_2HO_3 + NH_3 = C_2NH + 3HO$, or to that of cyanogen from oxalate of ammonia, $C_2O_3 + NH_3 = C_2N + 3HO$. (*Fehling in An. der Ch. u. Phar.* xlix. 91. 1844.)

B. of Baryta and Strontia are sparingly soluble in cold, but more freely in boiling water, from which they are deposited in fine acicular crystals.

B. of Lime. Crystallizes with 1 eq. of water of crystallization, in brilliant flexible needles or

prisms, which require for solution 20 parts of cold, and somewhat less of boiling water. The products obtained by the distillation of this salt have been examined by Peligot and Mitscherlich. Two fluid products are thus obtained, the benzone $C_{13}H_5O$, and benzole $C_{12}H_6$; then naphthalin $C_{10}H_8$; the residue is carbon and carbonate of lime, and carbonic oxide is evolved. See below under BENZYL.

B. of Magnesia crystallizes in feathery needles, very soluble in water, efflorescent in air.

B. of Alumina. Formed by adding the alkaline benzoates to the salts of alumina, a crystalline precipitate, which is redissolved by heat.

Benzoates of *glucina*, *yttria*, and *zirconia*, are sparingly soluble gelatinous precipitates.

Protobenz. of Manganese. Transparent needles, unchangeable in the air, soluble in 20 parts cold water, difficultly soluble in alcohol.

Protobenz. of Iron. Crystallizes in needles, efflorescent, and becoming yellow in the air, soluble in water and alcohol.

Perbenz. of Iron. $Fe_2O_3 \cdot 3BzO$. The neutral salt may be obtained in crystals, which are dissolved in water and alcohol, with the separation of a basic salt; salts of the peroxide of iron, to the solutions of which so much ammonia has been added, that they lose their acid reaction and appear yellow, precipitate with a neutral alkaline benzoate a reddish white basic salt; or if an excess of ammonia has been used, the solution appears red, and a slight precipitate remains after some hours' repose, a yellowish brown precipitate, which is still more basic and insoluble in water; it falls as a bulky gelatinous mass, which, when dried and exposed to a red heat, leaves 25 per cent. of peroxide of iron, indicating the formula $2Fe_2O_3 \cdot 3BzO + 12HO$. The former reddish white voluminous precipitate is decomposed by washing with hot water, when a soluble acid benzoate of the peroxide of iron is dissolved, and the yellowish brown basic compound left; the decomposition is prevented by washing first with an aqueous then an alcoholic solution of sal-ammoniac. The benzoate of ammonia is sometimes used with the necessary precautions for separating peroxide of iron from the oxides of manganese, nickel, and zinc, which are not precipitated by it; it cannot be employed if the solution contain any of the proper earths, as these also form very sparingly soluble salts with benzoic acid.

B. of Nickel and Cobalt are soluble and crystallizable, the former green, the latter red; and form basic salts by boiling with their hydrates or carbonates. *B. of Tin and Bismuth* are white precipitates, the latter soluble in excess of benzoic acid. *B. of Uranium* is pale yellow; of *Copper* green when dry, soluble in dilute acetic acid, insoluble in alcohol.

B. of Lead. A very sparingly soluble white crystalline powder, but soluble in acetic acid, from which it may be obtained in crystals resembling benzoic acid; it contains 2 eq. water, the half of which is retained at 212° . Form. $PbO, BzO + 2HO$. A basic salt is obtained by precipitating a benzoate of the alkalies by the diacetate of lead in the form of a white anhydrous insoluble powder. Form. $3PbO, 2BzO$.

B. of black oxide of Mercury, a white, insoluble, caseous or crystalline precipitate. The salt of

red oxide is soluble, but with an excess of red oxide forms a white powder, difficultly soluble in water and alcohol, sublimes in feathery crystals.

B. of Silver. Dilute boiling solutions of a neutral benzoate of an alkali and nitrate of silver being mixed, yield, as they cool, soft, flat needles of a white color and strong lustre, and very similar to benzoic acid, which are anhydrous benzoate of oxide of silver; they blacken by exposure to light. Thrown down from concentrated solutions, it forms a curdy, crystalline mass, which, dissolved in hot water, yields a dark-colored solution owing to the reduction of silver; the salt is again deposited in the described form. Formula, $AgOBzO$.

B. of Gold and Platinum. Obtained by dissolving the oxides, precipitated by potassa, in a boiling mixture of acid and water; are yellow crystals, unalterable in air, sub-soluble in water, insoluble in alcohol. They are probably double salts. The salt of *Palladium* is a white precipitate, soluble in much water.

DECOMPOSITION OF BENZOIC ACID AND BENZOATES.

Benzoate of ammonia yields, by distillation, a compound called by Fehling benzonitril (see above). Benzoate of lime yields BENZONE and BENZOLE. Benzoic acid yields with anhydrous sulphuric and nitric acids, and with chlorine and bromine, several distinct acids, which here follow:

1. *Sulphobenzoic acid.* Syn. Hyposulphobenzoic acid. A bibasic acid, discovered by Mitscherlich. It is prepared by adding to a solution of acid sulphobenzoate of baryta, diluted sulphuric acid, till the baryta is entirely precipitated. The filtered solution is evaporated, at first over the open fire, and at last in vacuo with sulphuric acid, when the sulphobenzoic acid crystallizes. In the formation of this acid by the action of anhydrous sulphuric acid on benzoic acid, 2 eq. sulphuric acid and 1 eq. benzoic acid produce water and sulphobenzoic acid; $C_{14}H_5O_3 + 2SO_3 = C_{14}H_4O_2 + 2SO_3 + 2HO$. Form. $C_{14}H_4O_2 + 2(SO_3, HO)$, or $C_{14}H_4O_3 + S_2O_5 + 2aq$.

It forms a colorless crystalline mass, deliquescent in a moist atmosphere, having a strong sour taste. It bears a heat of 300° without decomposition; and is not decomposed by boiling with hydrochloric acid nor by nitric acid. Solutions of barytic salts cause in its solution a precipitation of acid sulphobenzoate of baryta, in crystals, on cooling, if the solutions be strong.

Sulphobenzoates. This acid forms two series of salts. The neutral salts contain 2 eq. metallic oxide; the acid salts, dried at 212° , 1 eq. metallic oxide and 1 eq. water. All the salts of this acid, when melted with an excess of hydrate of potassa, leave a residue containing a mixture of sulphate, sulphite, and carbonate of potassa.

The acid salt of potassa crystallizes in dry air in crystals which are deliquescent in moist air; the neutral salt forms large efflorescent crystals. The soda salts crystallize.

Acid Sulphobenzoate of Baryta. The vapors of anhydrous sulphuric acid are conducted into

a dry receiver, containing crystallized benzoic acid, and surrounded with cold water. The sulphuric acid combines with the benzoic acid, forming a translucent mass, which is mixed with water as soon as the crystalline structure of the benzoic acid has disappeared. After the acid liquid, by standing, has deposited any excess of benzoic acid, it is neutralized by carbonate of baryta, evaporated and mixed with hydrochloric acid; when on cooling it deposits the acid sulphobenzoate of baryta in crystals. It may be rendered perfectly colorless by animal charcoal, and purified from muriatic acid by repeated crystallization. It forms transparent, oblique rhombic prisms, generally twincrystals, soluble in 20 parts of cold water and much less of boiling water. It contains 3 eq. water of crystallization, which is expelled by a heat of 212° .

The Neutral Salt of Baryta is obtained by boiling the preceding salt with carbonate of baryta: it is more soluble than the acid salt; difficultly crystallizable, and bears a heat of 630° without decomposition.

The Neutral Salt of Lead is obtained by mixing a hot dilute solution of the last salt with one of acetate of lead. It crystallizes on cooling, in fine, white, silky needles arranged in radiated tufts; very sparingly soluble in cold, more easily in hot water. It contains 2 eq. water of crystallization.

The silver salt, similarly obtained, is very soluble, forms small, yellowish crystals, which lose 2 eq. water by drying.

Fehling and others hold that the acid in this series is $C_{14}H_4O_3 + S_2O_5 + 2HO$, or hyposulphuric acid, with the radical $C_{14}H_4O_3$; but it may be expressed by the formula, $C_{14}H_4O_2 + 2(SO_3, HO)$, which agrees better with its saturating power, and in which 1 or 2 eq. of water are exchanged in the salts for 1 or 2 eq. base. This $C_{14}H_4O_2$ would therefore constitute a new radical. (*Berz. Jahresh.* xix. 408.)

2. Nitrobenzoic acid. Formed by the action of nitric acid on cinnamic acid (*Plantamour*), or on benzoic acid (*Mulder*). Boil benzoic with nitric acid until the evolution of nitric oxide ceases; the new acid crystallizes out on cooling, and is purified by recrystallization. It forms tufts of needles, which lose nothing at 212° , fuse at 261° , beginning to sublime previously; sublime wholly and without change when pure; soluble in 400 cold, in 10 boiling water, and when in excess fuse under the boiling solution to an oily liquid, which congeals on cooling; very soluble in alcohol and ether; sublimes unchanged in chlorine; soluble in nitric, muriatic, and sulphuric acids without alteration, but when heated strongly in the sulphuric it is partially decomposed, yielding a body not further examined.

Composition. $C_{14}H_5NO_8$, from which Mulder deduces the formula, $C_{14}H_4O_4 + NO_3 + HO$, but Berzelius points out its resemblance to the sulphobenzoic acid, in which the same organic radical is here combined with 1 eq. nitric acid, and gives the more probable formula, $C_{14}H_4O_2 + NO_5 + HO$, for the crystallized acid, and $C_{14}H_4O_2 + AgO, NO_3$ for the silver salt. It is a strong acid, forming salts generally soluble in water and alcohol; when dry and strongly

heated, they explode; distilled at a gentle heat, they yield nitrobenzid. The nitrobenzoates of potassa and soda are crystalline, very soluble; the ammoniacal salt loses ammonia by evaporation, and then crystallizes in white needles, with the formula $\left. \begin{matrix} NH_4O, C_{14}H_4O_2, NO_5 \\ + HO, C_{14}H_4O_2, NO_5 \end{matrix} \right\}$ or $2(C_{14}H_4O_2, NO_5) + NH_4O$. The barytic salt $C_{14}H_4O_2 + NO_5 + BaO$ forms fine needles with 4 eq. water, which it loses at 212° ; the strontian salt, $2(C_{14}H_4O_2, NO_5) + SrO + 5HO$, loses 2 eq. at 212° , the rest at 266° ; the lime salt, $C_{14}H_4O_2 + NO_5 + 2HO$, loses 1 eq. water at 266° , the other at 374° ; the zinc salt, $C_{14}H_4O_2 + NO_5 + 5HO$, crystallizes in leaves, loses its water at 266° ; prepared by double decomposition, it precipitates as a gelatinous basic salt; the salt of manganese has 4 eq. water, loses 2 at 158° and the others above 239° ; the salt of peroxide of iron, formed by double decomposition, is a flesh-colored powder, anhydrous, with the formula, $3(C_{14}H_4O_2 + NO_5) + Fe_2O_3$; the lead salt formed by double decomposition is basic, but by adding subacetate of lead to a boiling, moderately-strong solution of the acid it separates in fine crystals, neutral and anhydrous; the copper salt is a blue powder with 1 eq. water; the anhydrous silver-salt is slightly soluble, crystallizing in spangles, from which a little acid sublimes at 212° ; heated to 392° , it yields nitrobenzid largely, which can be easily purified over carbonate of lime. (*Berz. Jahresh.* xx. 287.)

3. Benzoic acid, with chlorine and bromine. Herzog describes two bodies resulting from the action of chlorine and bromine exposed to the light of the sun. With the former a reddish tough mass is obtained, which is treated with potassa, the solution decolorized by animal charcoal, and nitric acid added, which precipitates a white crystalline acid resembling the benzoic, but containing chlorine; it fuses at 208.4° , is slightly soluble in cold, largely in boiling water, in alcohol and ether. (*Berz. Jahresh.* xxi. 258.)

4. Bromobenzoic acid. Prep. Dry benzoate of silver and bromine, the latter in an open tube, are introduced into a stoppered bottle, which is then closed, and the whole left to itself at the ordinary temperature. The vapor of bromine rising out of the tube is absorbed by the salt, which is decomposed thereby. As soon as the red vapors of unabsorbed bromine are seen in the bottle, the reaction is complete. The mass is now treated with ether, which dissolves bromobenzoic acid, and leaves bromide of silver undissolved. By the evaporation of the ether, the acid is obtained in the form of a brown oily matter, which, after a time, becomes solid and crystalline. It commonly contains a little benzoic acid and an oily matter, to which latter its color is owing. To purify it, it is combined with potassa, the solution decolorized by animal charcoal, and the salt then decomposed by nitric acid, when pure bromobenzoic acid separates. In this process, when bromine acts on benzoate of silver, both the benzoic acid and the oxide of silver are decomposed. From 2 eq. oxide of silver, 2 eq. oxygen pass over to the elements of the acid. Bromide of silver is formed, 1 eq. hydrogen out of 2 eq.

benzoic acid unites with 1 eq. bromine; and is separated as hydrobromic acid. Finally 1 eq. bromine takes the place of the hydrogen. $(C_{28}H_{10}O_8 + Ag_2) + Br_4 = (C_{28}H_9BrO_8) + 2 AgBr + HBr$. The anhydrous bromobenzoic acid, which is here formed, combines with 2 eq. water when separated from its salts by a stronger acid. Formula, $C_{28}H_9BrO_8 + 2HO$.

A colorless, crystalline mass, fusible at 212°, subliming at 480°, with a partial decomposition, and leaving a residue of carbon; sparingly soluble in water, very soluble in alcohol, ether, and pyroxylic spirit; inflammable, burning with a smoky flame, edged with green. Its solutions, added to nitrate of silver, produce no precipitate of bromide of silver.

It forms soluble salts, some of which crystallize, with the alkalies, alkaline earths, and the oxides of zinc, cobalt, nickel, mercury, and silver; and sparingly soluble salts with oxides of lead and copper and black oxide of mercury. The bromobenzoate of peroxide of iron is insoluble, and resembles the benzoate of that oxide.

BENZOÏN. *Chem.* (*Robiquet and Boutron Charlard.*) It is produced by the contact of alkalies with the commercial oil of bitter almonds; but not with the pure hyduret of benzyl. 1. When the crude oil is distilled with hydrate of lime and protochloride of iron, the residue is a mixture of benzoïn with lime and hydrated protoxide of iron. It is treated with hydrochloric acid, which dissolves the iron and lime; and the undissolved benzoïn is purified by solution in alcohol with the aid of animal charcoal. 2. The crude oil is dissolved with the aid of heat in lime or baryta-water, and the solution, in a stoppered-bottle, is kept for several hours at the temperature of 212°, when it becomes filled with fine, snow-white, flaky crystals, which, if dissolved in hot alcohol, are deposited in a state of purity on cooling. 3. The best method of preparing it consists in mixing a solution of caustic potassa in alcohol, with its equal volume of crude oil of bitter almonds. After a little time the mixed liquids become apparently solid from the quantity of small crystals of benzoïn formed in them; these must be purified by crystallization from alcohol. They form transparent, colorless, very brilliant prisms, without smell or taste; melting at about 230°, volatilizing unchanged at a higher temperature; inflammable, burning with smoke; insoluble in cold, little soluble in hot water, more soluble in boiling than in cold alcohol. Benzoïn is soluble in oil of vitriol with a violet-blue color; if the solution be heated, becoming brown, green, and at last black, with disengagement of sulphurous acid. It is insoluble in aqueous solutions of the alkalies. If melted with hydrate of potassa, benzoate of ammonia is formed, with disengagement of hydrogen gas. An alcoholic solution of potassa dissolves it with a violet-blue color; and if the solution be boiled, it passes into benzoic acid. Its vapor, passed through a red-hot glass tube, is converted into an oily substance with the odor of bitter almonds (hyduret of benzyl). It is decomposed by bromine. Chlorine gas, when made to act on melted

benzoïn, deprives it of some hydrogen, and converts it into benzile.

The part which hydrocyanic acid plays in the production of benzoïn by the action of alkalies on hyduret of benzyl is still obscure. It is certain that benzoïn cannot be obtained from pure hyduret of benzyl; but that it appears after a few hours, when a little hydrocyanic acid is added to a hot solution of the pure hyduret in barytic water, if the solution be kept hot. After the separation of the benzoïn, the liquid contains ammonia and benzoic acid, with a mere trace of formobenzoic acid.

Formula of benzoïn, $C_{14}H_6O_2$. It is therefore isomeric with hyduret of benzyl.

Hydrobenzoïnamide, or *Benzoïnamide*, has the same composition as hydrobenzamide. It is obtained by gently heating benzoïn with caustic ammonia; and forms a white, tasteless, inodorous powder, volatile without decomposition.

Hydrocyanate of Benzoïn. (*Zinn.*) *Prep.* A mixture of 4 pts. of oil of bitter almonds, and 1 pt. of anhydrous prussic acid is added to 1 pt. of a solution of caustic potassa of spec. grav. 1.25, diluted with 6 times its bulk of alcohol. The whole should be gently heated, and laid aside for twenty-four hours, after which, fine, white, flocculent crystals form, which may be purified by crystallization from alcohol. It is difficultly soluble in alcohol and ether; in sulphuric acid it dissolves with a green color; in muriatic acid, potash-lye, and water, it is insoluble. Its formula is $C_{46}H_{18}N_2O_4$; hence it is formed of 3 eq. hyduret of benzyl and 2 eq. prussic acid, minus 2 eq. water.

BENZOLE. *Chem.* *Syn.* *Benzin, Mitscherlich.* First discovered by Faraday among the products of the destructive distillation of organic substances; afterwards noticed by Mitscherlich as the chief product of the decomposition of crystallized benzoic acid by hydrate of lime at a high temperature.

Prep. 1 part of crystallized benzoic acid, intimately mixed with 3 parts of slaked lime, is subjected to a distillation, and the oily liquid obtained purified by re-distillation with water, or with hydrate of lime and dry lime.

Prop. A clear, colorless liquid of a peculiar, ethereal, agreeable odor; boils at 186°; spec. grav. in the liquid form 0.85; in the form of vapor 2.738 at 60°. It freezes at 32° into a crystalline mass resembling loaf-sugar, which melts again at 44°. It is insoluble in water, soluble in ether and alcohol, not altered by hydrated acids, not acted on by potassium, which retains its lustre in the liquid. From its spec. grav. in the state of vapor, it appears to contain 3 vols. hydrogen and 3 vols. carbon vapor. Its formula is C_2H ; but it is probable that the formula $C_{12}H_6$ represents its true constitution. It is polymeric with FORMYL (which see).

Its production from benzoic acid is thus easily explained; for if from 1 eq. crystallized benzoic acid we take away (by the lime) 2 eq. carbonic acid, benzole remains. $C_{14}H_6O_4 - C_2O_4 = C_{12}H_6 = 6 C_2H$.

Decomposition of Benzole.

Sulphobenzide. (*Mitscherlich.*) Benzole and anhydrous sulphuric acid are brought together,

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when they form a viscid liquid, without special signs of decomposition. The compound dissolves in a small quantity of water, but by the addition of more water sulphobenzide is precipitated, which may be obtained in crystals by solution in ether and spontaneous evaporation. Here 1 eq. sulphuric acid and 1 eq. benzole produce 1 eq. water and 1 sulphobenzide. It is a colorless, inodorous, indifferent body, melts at 212° , and sublimes without decomposition at a higher temperature; soluble in strong acids without change; unaltered by chlorine or bromine at common temperatures, but decomposed when heated in them. Form. $C_{12}H_5SO_2$.

Hyposulphobenzidic Acid. This acid is contained in the liquid from which, in the above process, the sulphobenzide has separated. It is also formed by dissolving sulphobenzide in oil of vitriol, and by the action of the fuming sulphuric acid on benzole. It may be considered as composed of oil of vitriol and sulphobenzide, which explains its formation. It is obtained pure by decomposing the hyposulphobenzidate of copper by sulphuretted hydrogen. It forms a very sour liquid, which crystallizes when evaporated to the consistence of syrup, and bears a heat of nearly 400° without decomposition. Formula, $C_{12}H_5S_2O_3$; but it may also be represented by the formula, $(C_{12}H_5SO_2) + SO_3$, or a sulphate of sulphobenzide. For by dissolving benzole in warm oil of vitriol this acid is produced, containing the eq. of water in the sulphuric, which may be exchanged for other bases in its salts. (Berz.)

Hyposulphobenzidate of Baryta. A soluble salt, crystallizing indistinctly. It is obtained by dissolving in fuming oil of vitriol as much benzole as it will take up, mixing the solution with water, filtering to separate the sulphobenzide, and neutralizing the liquid with carbonate of baryta. A second filtration separates the sulphate of baryta which is formed at the same time, and the filtered liquid contains the barytic salt in question.

Hyposulphobenzidate of Copper. The solution of the preceding salt is accurately precipitated by sulphate of copper, and the sulphate of baryta separated by filtration. The filtered liquid, being evaporated, yields, on cooling, large regular crystals of hyposulphobenzidate of copper. This salt contains water of crystallization, which it loses at 340° . It may be heated at 430° without decomposition. The salts of potassa, soda, ammonia, oxides of zinc, iron, and silver are crystallizable compounds.

Nitrobenzide. (Mitscherlich.) Prepared by adding gradually to warm, red, and fuming nitric acid as much benzole as it can dissolve, adding water, and allowing the whole to cool, when nitrobenzide precipitates; it is washed with water and distilled. It is at 60° a yellow liquid of an intensely sweet taste, and an odor resembling oil of cinnamon and bitter almonds. It boils at 415° ; spec. grav. of the liquid 1.209, of the vapor .4294. It crystallizes at 38° in needles, insoluble in water, soluble in alcohol and ether in every proportion. Nitrobenzide is soluble in diluted acids, from which it is precipitated by water. It is decomposed by oil of vitriol, but not by alkalis. Formula,

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$C_{12}H_5NO_4$, which might be expressed $C_{12}H_5O + NO_3$, resembling nitrous ether with a radical different from ethyl.

Azobenzide. (Mitscherlich.) Nitrobenzide is dissolved in alcohol, and heated with solid hydrate of potassa: the red solution which is formed is then distilled. At first alcohol, then azobenzide distils over, and they are collected separately. It forms large red crystals, fusible at 150° , boiling at 380° , insoluble in cold, slightly soluble in warm water, very soluble in alcohol and ether. Formula, $C_{12}H_5N$.

Chloride of Benzole. (Mitscherlich and Peligot.) Formed by the action of chlorine gas on benzole aided by the sun's rays. The benzole changes into a crystalline mass of chloride of benzole, which is a colorless solid, fusible at 270° , and boiling with partial decomposition at 550° ; insoluble in water, soluble in alcohol and ether, crystallizing easily from the latter solution. Formula, C_7HCl , or $C_{12}H_6Cl_6$.

Chlorobenzide. (Mitscherlich.) When the preceding substance is distilled, half of its chlorine and hydrogen are separated, especially with the aid of an alkali, such as hydrate of lime. It forms a colorless oily liquid, which boils at about 410° ; spec. grav. of the liquid at 45° , 1.457; of the vapor, 6.37; insoluble in water; readily soluble in alcohol, ether, and benzole. Formula, $C_{12}H_5Cl_3$.

Benzole forms corresponding compounds with bromine prepared in a similar manner; the bromide is less soluble in alcohol and ether than the chloride.

BENZONE. (Mitscherlich and Peligot.) Syn. Carbobenzide, Mitsch. It is produced in the distillation of benzoate of lime. To obtain it, the raw product of the distillation of benzoate of lime is heated, first in the water-bath, and then gradually up to 920° , as long as benzole passes over. The residue is then distilled separately. The product is now benzone, holding in solution a certain quantity of naphthalene, which, by exposure to a cold of -5° , crystallizes out, and leaves, according to Peligot, pure benzone. Benzone is a colorless or pale-yellow, viscid, oily liquid, heavier than water. It is decomposed by sulphuric acid or chlorine, but not by nitric acid or caustic potassa. Form. $C_{13}H_5O$. It may be derived from benzole and carbonic acid, by the removal of the elements of water; $C_{12}H_6 + CO_2 = (C_{12}H_5 + CO) + HO$.

BENZYL. Chem. Syn. Benzoyl, Benzule. The hypothetical radical of a series of compounds, obtained from the volatile oil of bitter almonds. (See ALMOND.) By oxidation of the pure oil, benzoic acid is produced, which forms the benzoates; and by the action of sulphuric and nitric acids and bromine, sulpha, nitro, and bromobenzoic acids. See these under BENZOIC ACID. By distilling benzoic acid with lime, it gives rise to benzole and benzene; and from benzole are formed sulpha, nitro, azo, and chloro-benzide, sulpha-benzidic acid, and chloride of benzole. See BENZOLE and BENZONE. Benzoate of ammonia yields by distillation benzonitril. See under BENZOIC ACID.

From the hyduret of benzyl (pure vol. oil of bitter almonds) are obtained the chloride, bromide, iodide, cyanide, and sulphuret of benzyl,

benzamide, formobenzoic acid, and benzoate of the hyduret: and by its decomposition with ammonia, are produced hydrobenzamide, benzhydramide, azo and nitro-benzyl. By the contact of alkalis with the commercial or crude oil, benzoin is formed, which produces benzoinamide with ammonia, benzile, by the action of chlorine, and benzilic acid, by an alcoholic solution of potassa. The compounds mentioned in this paragraph are described under the present article.

All these derivatives from the hyduret of benzyl are here offered in a tabular form with their formulæ.

Formulæ.

Benzyl.....	$C_{14}H_5O_2$, or Bz.
Benzoic acid, anhydrous	BzO.
Benzoic acid, hydrate of	$BzO + aq.$
Hyduret of benzyl.....	BzH.
Chloride do.	BzCl.
Bromide do.	BzBr.
Iodide do.	BzI.
Sulphuret do.	BzS.
Cyanuret do.	BzCy.
Benzamide do.	$BzNH_2$, or BzAd.
Formobenzoic acid ...	$BzH + C_2HO_3$.
Benzoate of hyduret of benzyl.....	$BzO + 2BzH$.
Hippuric acid.....	$BzAd + C_4HO_3 + aq.$
Sulphobenzoic acid ...	$C_{14}H_4O_3S_2O_5 + 2 aq.$
Bromobenzoic acid ...	$C_{28}H_9O_5Br_2 + 2 aq.$
Benzole.....	$C_{12}H_6$.
Sulphobenzide.....	$C_{14}H_5SO_2$.
Hyposulphobenzidic acid	$C_{14}H_5S_2O_5$.
Nitrobenzide.....	$C_{12}H_5NO_4$.
Azobenzide.....	$C_{12}H_5N$.
Chlorobenzole.....	$C_{12}H_6Cl_6$.
Chlorobenzide.....	$C_{12}H_3Cl_3$.
Benzone.....	$C_{13}H_5O$.
Hydrobenzamide.....	$C_{28}H_{18}N$.
Benzimide.....	$C_{28}H_{11}N_3$.
Benzoin.....	$C_{14}H_6O_2$.
Benzile.....	$C_{14}H_5O_2$.
Benzilic acid.....	$C_{28}H_{11}O_5 + aq.$

HYDURET OF BENZYL.

Syn. Volatile or essential oil of bitter almonds. Hydrobenzyl. Ger. Benzoylwasserstoff. Prep. For the formation of the essential oil, consult the articles ALMOND and AMYGDALIN. Thus prepared it contains benzoic acid, benzoin, and hydrocyanic acid: it is made into a thin paste by being mixed with hydrate of lime, and a solution of chloride of iron, and redistilled; the oil which passes over is freed from the admixture of water by standing over dry chloride of calcium, or freshly powdered quick-lime.

Prop. A transparent colorless fluid, of a strong peculiar odor and burning taste; spec. grav. 1.043, refracts light strongly, boils at 356° ; soluble in 30 parts of water (see bitter-almond water under AMYGDALIN), and mixes with alcohol and ether; its vapor is inflammable, and burns with a brilliant but smoky flame; it may be transmitted through red-hot glass tubes without decomposition. By exposure to the air, to dry or moist oxygen, it absorbs 2 eq. oxygen, and is converted into hydrated benzoic acid; the same change is effected, with the decomposition of water and

the evolution of hydrogen, by exposing it to a high temperature with hydrate of potassa. Treated with an alcoholic solution of hydrate of potassa, it congeals in the course of a few moments to a mass of benzoate of potassa, which separates, when the alcohol is found to contain an oily substance not yet examined. By the action of chlorine or bromine, chloride or bromide of benzyl, together with chlorohydric or bromohydric acid is formed; if water be present, there is formed at the same time either benzoate of hyduret of benzyl, or benzoic acid. When gently heated with a solution of ammonia, it is converted into hydro-benzamide. It is dissolved by concentrated sulphuric acid with the aid of a gentle heat, but at a higher temperature the solution becomes first red and then black, and evolves sulphurous acid. It unites with anhydrous sulphuric acid, forming a peculiar acid, which is not precipitated by baryta. (Mitscherlich.) Nitric acid dissolves the hyduret of benzyl, and converts it with difficulty into benzoic acid. It is poisonous when taken internally in the pure state. Formula, $C_{14}H_6O_2$ or Bz + H; eq. = 107.68.

Chloride of Benzyl. (Wöhler and Liebig.) Prepared by passing a stream of chlorine-gas through anhydrous hyduret of benzyl, as long as chlorohydric acid is evolved; the liquid which has acquired a yellow color is then heated, to drive off all free chlorine, when it again becomes colorless.

Prop. A colorless liquid of a peculiar unpleasant odor, which attacks the eyes; spec. grav. = 1.196; the vapor is combustible and burns with a smoky flame tinged with green; it is slowly decomposed into chlorohydric and benzoic acids by cold water, more rapidly by hot water; added to an alkali, a benzoate of the alkali and a metallic chloride are formed; it may be distilled unaltered from anhydrous lime or baryta, and dissolves sulphur and phosphorus without change; when brought into contact with the protochloride of phosphorus, a strong heat is developed, with the formation of the perchloride of phosphorus and a colorless oily substance which has not been further examined. It is decomposed by ammoniacal gas into benzamide and chlorohydric acid; by alcohol, into benzoate of oxide of ethyl and chlorohydric acid; it mixes without change with ether, and the bisulphuret of carbon. Formula, $C_{14}H_5O_2Cl$, or BzCl.

Bromide of Benzyl. (Wöhler and Liebig.) Prep. like the chloride. It forms colorless scaly crystals, which become brown by exposure to the air; decomposed by water and the alkalies, in the same manner as the chloride; dissolves without change in ether and alcohol. Form. $C_{14}H_5O_2Br$, or BzBr.

Iodide of Benzyl. (Wöhler and Liebig.) Prep. By distilling chloride of benzyl and iodide of potassium, when it is obtained as a crystalline mass, colored brown by an excess of iodine. When pure it forms colorless scaly crystals, which are very fusible and become brown in the air; it is acted upon by water and alkalies like the preceding compounds. Form. $C_{14}H_5O_2I$, or BzI.

Sulphuret of Benzyl. (Wöhler and Liebig.) Prep. By distilling the chloride of benzyl with sul-

phuret of lead. It forms a yellow oil of a soft crystalline mass, which, when cooled, has a peculiarly unpleasant smell; scarcely acted on by boiling water, but, when treated with solution of potassa, it is slowly converted into benzoic acid and sulphuret of potassium; it is combustible, and dissolves unchanged in alcohol and ether. Form. $C_{14}H_5O_2S$, or BzS .

Cyanide of Benzyl. (Wöhler and Liebig.) *Prep.* by distilling chloride of benzyl with cyanide of mercury. A yellow oil, which, when rectified, becomes colorless; its smell is similar to that of cinnamon, and it irritates the eyes violently; taste pungent and sweetish, with an after-taste of prussic acid; inflammable. Form. $C_{14}H_5C_2Cy$, or $BzCy$.

Benzamide. (Wöhler and Liebig.) *Prep.* Formed by the action of chloride, bromide, or cyanide of benzyl with dry ammoniacal gas; also a product of the decomposition of hippuric acid by superoxide of lead. (Fehling.) 1. Chloride of benzyl is saturated with dry ammonia, by passing the gas into it, taking out the compound several times, crushing it and reacting on it by ammonia; the white solid mass produced, which is a mixture of sal-ammoniac and benzamide, is finely powdered, and well washed with cold water to remove the sal-ammoniac. The residue is dissolved in boiling water, and the benzamide crystallizes on cooling. 2. Hippuric acid is boiled with superoxide of lead, when carbonic acid is disengaged, and hippurate of lead and benzamide are formed, which remain dissolved. Sulphuric acid is now added, cautiously avoiding excess, and the whole is again boiled with a new portion of superoxide of lead. These operations are repeated till all the hippuric acid has been destroyed; and the liquid, when freed from lead, yields crystals of benzamide by evaporation. Chloride of benzyl with ammonia produces benzamide and free hydrochloric acid, which is converted into sal-ammoniac by the ammonia in excess; $BzCl + AdH = BzAd + HCl$. Hippuric acid contains the elements of fumaric acid and benzamide (see table). When boiled with superoxide of lead, the organic acid is converted into carbonic acid and water, while the benzamide is liberated.

Prop. Benzamide forms right rhombic prisms, or 4-sided pearly scales. A concentrated hot solution by slow cooling forms a soft mass of minute crystals, which spontaneously pass into scales of considerable size, after some time. The crystals are colorless and transparent, and melt at about 240° . At a higher temperature they are volatilized, producing an inflammable vapor. It is sparingly soluble in cold water; freely and without change in hot water; soluble in alcohol and ether. Alkalies and acids, water being present, decompose benzamide, with the production of benzoic acid and ammonia. When benzamide is gently heated with anhydrous baryta, a violent reaction takes place, with disengagement of heat. Benzoate of baryta is formed; ammonia is disengaged; and a colorless oily liquid distils over, consisting chiefly of benzole. Formula of benzamide, $C_{14}H_7NO_2$, or $Bz + NH_2$, or $BzAd$.

Formobenzoic Acid. Syn. Formiate of Hyduret of Benzyl. (Winkler.) *Prep.* by dissolving commercial oil of bitter almonds in water, adding chlorohydric acid, and evaporating in a gentle heat. The dry residue, consisting of formobenzoic acid and sal-ammoniac, is treated with ether, which dissolves the new acid. It is obtained in crystals by evaporating the ether, and decolorized by animal charcoal.

Prop. A white granular powder, imperfectly crystallized, or a scaly crystalline mass, which has a strong sour taste, and a faint odor of almonds. When heated, it melts, with disengagement of water, into an oily fluid, which, at a higher temperature, is decomposed, with a pleasant odor, like that of hawthorn blossom, and leaves behind a bulky coal. It is very soluble in water, alcohol, and ether; and decomposes, with the aid of heat, the salts of acetic, carbonic, and benzoic acids. Its aqueous solution, heated with superoxide of manganese, is resolved into carbonic acid and hyduret of benzyl. The same result ensues from the action of nitric acid or of chlorine.

The formobenzoic acid is produced, in the process above described, in the following manner. The commercial oil of bitter almonds contains hydrocyanic acid mixed with the pure oil or hyduret of benzyl. In contact with a strong mineral acid and water, the cyanohydric acid (see that article) is resolved into formic acid and ammonia, the former of which, while nascent, unites with the hyduret of benzyl to produce the new acid. Oxidizing agents, by the addition of 2 eq. oxygen, convert the formic acid into carbonic acid and water, while the hyduret of benzyl is set free. Formula of formobenzoic acid, $C_2HO_3 + C_{14}H_6O_2 + HO$, or $FoO_3 + BzH + HO$.

Formbenzoates. Metallic oxides readily combine with this acid, equivalent to equivalent, forming neutral salts. Those with potassa and soda are very soluble, and crystallize with difficulty. Formbenzoate of baryta crystallizes in small, hard, transparent prisms. The salt of silver, obtained by mixing solutions of formbenzoate of ammonia and nitrate of silver, appears as a heavy white crystalline and granular precipitate, which is soluble in hot water, and crystallizes on cooling in small anhydrous scales.

Benzoate of Hyduret of Benzyl. (Robiquet and Boutron Charlard.) It is obtained by saturating common oil of bitter almonds with moist chlorine gas. The liquid, after standing for some time, is converted into a semi-solid mass or crystals, which are to be washed with cold ether. It forms a dazzling white crystalline powder; or short, thin, transparent, and very brilliant four-sided prisms, insoluble in water, soluble in alcohol, slightly soluble in ether. It dissolves easily in alcohol saturated with caustic potassa, forming a colorless solution, out of which, after a time, benzoate of potassa crystallizes. It melts when heated, and may be sublimed without decomposition. Its formation by the action of moist chlorine on the oil is thus explained: the chlorine converts a part of the oil into hydrated benzoic acid, which, in the nascent state, combines with another por

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tion of the oil. $\text{BzH} + 2\text{HO} + \text{Cl}_2 = \text{BzO}$, $\text{HO} + 2\text{HCl}$. Formula, $\text{C}_{42}\text{H}_{15}\text{O}_8$, which may be thus written, $\text{C}_{14}\text{H}_6\text{O}_4 + 2(\text{C}_{14}\text{H}_6\text{O}_2)$, or BzO , $\text{HO} + 2\text{BzH}$, or 1 eq. benzoic acid + 2 eq. hyduret of benzyl.

Hyduret of Benzyl and Ammonia.

Hydrobenzamide. (Laurent.) *Prep.* Pure hyduret of benzyl is mixed in a stoppered bottle with twenty times its volume of concentrated ammonia, and the mixture kept for some hours at a temperature of from 100° to 120° . A crystalline mass is formed, which is washed with cold ether, and pure hydrobenzamide is left, which may be obtained in large and regular crystals by solution in alcohol and spontaneous evaporation. It forms regular octahedrons or rhombic prisms, tasteless, inodorous, and colorless; melting at 230° , and burning with a smoky flame; when distilled, it is decomposed with a residue of carbon. It is insoluble in water, soluble in alcohol, sparingly soluble in ether; the alcoholic solution, by boiling, is resolved into ammonia and hyduret of benzyl. When heated with chlorohydric acid, it is quickly and easily resolved into hyduret of benzyl and sal-ammoniac. Hydrate of potassa scarcely acts on it; but it undergoes a spontaneous decomposition by keeping. It is produced by the action of 2 eq. ammonia on 3 eq. of hyduret of benzyl, forming 1 eq. hydrobenzamide, and 6 eq. water. $3(\text{C}_{14}\text{H}_6\text{O}_2) + 2(\text{NH}_3) = 6\text{HO} + (\text{C}_{42}\text{H}_{15}\text{N}_2)$; which last is the formula of hydrobenzamide.

When the raw oil of bitter almonds is employed instead of the pure in this process, a yellow resinous mass is obtained, which is a mixture of hydrobenzamide, benzhydramide, azobenzyl, and nitrobenzyl. (*Ann. de Ch. et Ph.* lvi. 180.)

Benzhydramide has the same composition as hydrobenzamide. When the above-mentioned resinous mass is boiled with ether, both these substances are dissolved. By continued boiling, the hydrobenzamide is resolved into ammonia and hyduret of benzyl. The benzhydramide crystallizes on cooling, mixed with azobenzyl. Boiling alcohol dissolves the former, leaving the latter undissolved; and the benzhydramide is purified by repeated crystallization out of alcohol. It crystallizes in rectangular or 6-sided prisms, melts when heated into a transparent liquid, which, when cold, is not crystalline. A stronger heat decomposes it. It is not altered by boiling chlorohydric acid. The crystals are commonly mixed with others, whose form and reactions seem to indicate that they are a different substance.

Azobenzyl. The residue of the preparation of benzhydramide contains azobenzyl and nitrobenzyl. This residue is boiled with 100 pts. of alcohol, which, on cooling, deposits crystals of azobenzyl. It forms a fine white crystalline powder, decomposable by heat. Formula, $\text{C}_{42}\text{H}_{15}\text{N}_2$; according to which, it may be formed by the action of 3 eq. benzyl and 2 eq. ammonia. $3(\text{C}_{14}\text{H}_5\text{O}_2) + 2\text{NH}_3 = 6\text{HO} + \text{C}_{42}\text{H}_{15}\text{N}_2$.

Nitrobenzyl. The insoluble residue of the preparation of the last substance is nitro-

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benzyl. It forms a white tasteless powder, nearly insoluble in alcohol. By alkalis it is converted into another crystalline body not examined.

Benzyl and Sulphuret of Ammonium.

Hyduret of Sulphobenzyl. By mixing sulphuret of ammonium with a solution of bitter-almond oil in 10 pts. warm alcohol, it precipitates in the form of a white magma, which, when washed, resembles starch. Formula, $\text{C}_{14}\text{H}_5\text{S} + \text{HS}$.

Hyduret of Sulphazobenzyl. It crystallizes from the evaporated alcoholic solution, and has the formula $\text{C}_{63}\text{H}_{27}\text{NS}_6$.

Sulphydrate of Azobenzyl. Formed by keeping a mixture of equal volumes of bitter-almond oil, sulphuret of ammonium, and caustic ammonia in a closed bottle for several months; it is crystalline, soluble in boiling ether, from which it crystallizes. Form. $\text{C}_{14}\text{H}_5\text{N} + \text{HS}$.

The above compounds by sulphuret of ammonium were formed by Laurent, who discovered several others by the action of caustic ammonia on the crude oil of bitter-almonds. The latter have not been fully described.

Benzyl Theory.

The compound $\text{C}_{14}\text{H}_5\text{O}_2$ has been viewed as the organic radical of the benzylic series described in several of the preceding articles, but it is evident that we may regard benzoic acid, $\text{C}_{14}\text{H}_5\text{O}_3$, as a tritoxide of a radical C_{14}H_5 ; the two modes of viewing its composition are thus expressed, the former $\text{C}_{14}\text{H}_5\text{O}_2 + \text{O}$ (BzO), the latter $\text{C}_{14}\text{H}_5 + \text{O}_3$ (BzO_3), in which latter case Bz is the carbohydrogen C_{14}H_5 . Mitscherlich considers sublimed benzoic acid as anhydrous, and that it is composed of 1 eq. benzole $\text{C}_{12}\text{H}_6 + 2$ eq. carbonic acid $\text{C}_2\text{O}_4 = \text{C}_{14}\text{H}_6\text{O}_4$; that by contact with a base 1 eq. H from benzole and 1 eq. O from carbonic acid form water; that an anhydrous benzoate contains benzide C_{12}H_5 and oxalic acid C_2O_3 . The evidence is rather in favor of the benzyl theory, which we have adopted, although the series of compounds discovered by Laurent with vol. almond oil and sulphydrate of ammonium seem to prove that the carbohydrogen C_{14}H_5 is the only compound that remains constant in the benzylic series, and that it is therefore the true radical benzyl. Berzelius inclined to this view (*Perz. Chem.* vol. vi. 171—209) prior to the discovery of Laurent's compounds.

The benzyl series may be conveniently studied in the following order of the articles: Benzoic acid, Benzyl, Benzole, Benzoin, and Benzile, with reference to Almond and Amygdalin.

BERAUNITE. *Min.* Radiated and massive, with one perfect and one imperfect cleavage. $\text{H.} = 2 - 2.5$. $\text{G.} = 2.878$. Color hyacinth-red, becoming darker by exposure; translucent in thin splinters; lustre of cleavage-face pearly, of other surfaces vitreous; streak reddish ochrey yellow. Heated in a closed tube, it gives water; it fuses in the platinum-pincette, coloring the outer flame intensely bluish green. It contains water, phosphoric acid, and peroxide of iron, without any protoxide, but its exact

BERBERIN.

composition is unknown. It occurs at Hrbeck, near Beraun in Bohemia. (Plattner.)

BERBERIN. *Chem.* A yellow coloring principle obtained from the *Berberis vulgaris* (see **BARBERRY**) by Buchner and Herberger. The rasped root is several times extracted with boiling water, the infusion evaporated to an extract, treated with alcohol of 82 per cent., repeated as long as it comes off with a bitter taste, the greater part of the alcohol distilled off, and the residue placed in a cool position; the impure berberin, which separates, is strained from the mother-liquor, washed with a little cold water and dissolved in boiling water to saturation, from which it deposits on cooling; it is then crystallized from a saturated solution in boiling alcohol several times, and finally washed with a little cold spirits of wine. The fresh root yields 1.3 per cent.

Prop. Loose bright yellow, silky needles, of very bitter taste, soluble in 500 pts. water at 54°, in 250 pts. cold alcohol; very soluble in hot water and alcohol, soluble with warmth in fixed and volatile oils; insoluble in ether, naphtha, and bisulphuret of carbon. The solutions are neutral. It fuses at 266° with decomposition, and between 320° and 392° gives off the odor of burned horn. Decomposed by chlorine, sulphuric and nitric acids, the latter yielding oxalic acid; in phosphoric and muriatic acids unchanged; the vegetable acids dissolve it unaltered; by tannic it is precipitated. With the alkalis it yields brownish red salts, soluble and crystallizable; its aqueous solution precipitates nearly all the metallic oxides; those with mercury, tin, silver, antimony, cobalt, manganese, and baryta are yellow, with chlorides of iron, gold, and platinum orange-yellow, with copper and nickel green; it does not precipitate with lime-water, salts of lead, zinc, and protoxide of iron, but with basic acetate of lead. It yields characteristic precipitates with haloid salts, with bromide, iodide, and sulphocyanide of potassium light yellow, with cyanide reddish yellow, with prussiate of potassa a yellowish green, and with sulphuret of potassium a yellowish brown. Formula, $C_{33}H_{18}NO_{12}$. The crystals contain water which has not been determined.

Berberin imparts a fine yellow, without mordants, to linen, cotton, wool, and best to silk, but it becomes brighter and faster by tinsalt.

BERENGELITE. *Min.* Solid, scratched by the nail, with resinous lustre and fracture, a yellow streak, a disagreeable resinous odor, and slightly bitter taste; is insoluble in water, very soluble in alcohol and ether; and the alcoholic solution leaves by evaporation a soft viscid resin of a clear red color; combines with alkali to a resinate, which is insoluble as long as the solution contains an excess of alkali. It consists of

Carbon.....	72.338
Hydrogen.....	9.359
Oxygen.....	18.303

Formula, $C_{41}H_{16}O_3$.

It occurs similarly to the pitch locality of Trinidad, in large masses in the province of St. Juan de Berengela, Peru, and is employed

BERTHIERITE.

for paying boats and larger vessels and as a cement for buildings.

BERGAMOT, *Oil of. Perfum.* Syn. Essence of B. An essential oil obtained by pressure of the outer yellow rind of a variety of orange (*Citrus bergamia*), which is cultivated in Southern Europe. The commercial oil is pale yellow, very fluid, of an agreeable odor, spec. grav. 0.888, congeals a little below 32°; contains acetic acid, from which it is purified by shaking with water or an alkali; a camphor, Bergapten, gradually deposits from it in the course of time. It consists of at least two oils, one probably free from oxygen, for, when distilled with water, the first portions passing over contain 2.5 to 5 per cent. oxygen, but it has not been obtained free from the next oil which followed; the latter has a spec. grav. 0.856, boils at 361.4°, has the odor of the crude oil; is unaltered by caustic potassa, but passed in vapor over ignited quicklime yields a large quantity of benzole. Formula, $C_{15}H_{13}O$. From a similarity of origin, we might infer a close relation in its constitution to oil of lemons, and from the above formula it may be viewed as a hydrate of oil of lemons ($C_{10}H_8$), thus $2(C_{15}H_{13}O) = 3C_{10}H_8 + 2HO$.

It unites with chlorohydric acid gas, forming a colorless, neutral oil, with an odor similar to that of the liquid muriate of terpentine-oil, spec. grav. 0.896, boiling at 365°, burning with a smoky, green-edged flame. Its alcoholic solution is decomposed by warming with nitrate of silver. Probable formula, $C_{60}H_{50}ClO$, which may be expressed, $6C_{10}H_8 + HCl + HO$, or 6 eq. oil of lemons with 1 eq. chlorohydric acid and 1 eq. water.

Bergapten. Formed in the oil of begamot probably by oxidation. The deposit is separated from the oil by pressure, maceration with ether, and solution in boiling alcohol. It deposits, on cooling, in small colorless crystals, is inodorous and tasteless, fuses at 403.7°, sublimes unaltered, burns with a brilliant flame, slightly soluble in cold, extremely in boiling alcohol; is colored red by sulphuric acid and decomposed by nitric without the formation of oxalic acid. It unites neither with acids nor bases. Formula, C_9HO .

Use. Oil of bergamot is employed in perfumery, as an addition to Cologne-water, &c.

BERGMANNITE. *Min.* See **SCAPOLITE**.

BERTHIERITE. *Min.* Syn. Haidingerite.

Descrip. Prismatic, fibrous, granular, and massive, resembling gray antimony, but usually less splendid and less of a bluish tint.

Behavior. It fuses readily on charcoal, evolving antimonial fumes, and when the antimony is expelled, leaving a magnetic slag. The slag from the Bräunsdorf specimen gave the reaction of manganese with soda on platinum, and on charcoal, with the inner flame, gave oxide of zinc, which became greenish by ignition with cobalt solution. Soluble in muriatic, much more readily in nitromuriatic acid. (Berz. Ram.)

Analysis. 1. From Chazelles in Auvergne; 2. from Martouret-mine near Chazelles; 3. from Anglar in Dep. d. l. Creuse, all by Berthier, 4. from Bräunsdorf near Freiberg, by Rammeisberg:

BERYL.

	1.	2.	3.	4 a.	b.
Sulphur.....	30.3	28.81	29.18	30.575	31.326
Antimony.....	52.0	61.34	58.65	54.338	54.700
Iron	16.0	9.85	12.17	11.965	11.432
Zinc	0.3	—	—	trace	0.737
Manganese.....	—	—	—	0.456	2.544
	98.6	100	100	97.834	100.739

The formulas for 3 and 4 is $\text{FeS} + \text{SbS}_3$, and by making the sulphobase equal in each, we have the composition of 3 kinds:

For 1.	$3 \text{ FeS} + 2 \text{ SbS}_3$.
" 3 and 4.	$3 \text{ FeS} + 3 \text{ SbS}_3$.
" 2.	$3 \text{ FeS} + 4 \text{ SbS}_3$.

It is possible that they may all have the formula of 3 and 4, mingled in 1 with sulphuret of iron and in 2 with sulphuret of antimony, and the large quantity of gangue in the specimens examined by Berthier rather strengthens this view; or 1 may be viewed as a compound analogous to Jamesonite 2 ($\text{FeS} + \text{SbS}_3$) + FeS . See ANTIMONIAL ORES.

BERYL. *Min.* Syn. Rhombohedral Emerald, *Mohs*; Emerald; Aquamarine; Smaragd. *Ger.* Edler u. Gemeiner Beryll. *Fr.* Emeraude.

Description. Cryst. system, Hexagonal; the hexagonal prism M and terminal plane P predominate, sometimes combined with three 6-sided pyramids of 1st order, and the most acute having its 1st obtuser pyramid, a didodecahedron, and a 6-sided prism of the 2d order. M on main 6-sided pyramid = $119^\circ 53'$, P on the same = $150^\circ 7'$. P on the more acute py-

	1.	2.	3.	4.	5.	6.	7.
Silica	66.45	67.0	66.86	68.35	67.00	64.40	68.50
Alumina	16.75	16.5	18.41	17.60	19.64	14.00	15.75
Oxide of iron.....	0.60	1.0	2.00	0.72	0.53	—	1.00
Glucina.....	15.50	14.5	12.54	13.13	12.56	13.00	12.50
Lime	—	0.5	—	—	0.18	2.56	0.25
Oxide of chrome	—	—	—	(0.72)	—	3.50	0.30
	99.30	99.5	99.81	100.52	99.91	97.46	98.30

Form. ($\text{Be}_2\text{O}_3, 4 \text{ SiO}_3$) + 2 ($\text{Al}_2\text{O}_3, 2 \text{ SiO}_3$). It would be as close an approximation to Berzelius's analysis (4) to write more simply ($\text{Be}_2\text{O}_3, 3 \text{ SiO}_3$) + 2 ($\text{Al}_2\text{O}_3, 3 \text{ SiO}_3$). (*Ram.*)

Locality, &c. Emerald and beryl constitute one species, the former being the transparent varieties with a rich green color due to oxide of chrome. Found in primary rocks. The finest emeralds occur in limestone traversing hornblende-rock near Santa Fé de Bogota in Grenada. They are transparent, of a deep green color, often perfectly crystallized, and of a large size. Fine specimens occur also in Siberia, in Upper Egypt; at Canjargum in Hindostan; Salzburg in mica slate.

The term Aquamarine is applied to emerald of a sky-blue, or mountain-green color. The beryl (common) occurs at Finbo, Broddbo, Fossum in Sweden and Norway; Bodenmais; Rabenstein in Bavaria, &c., &c.

In the United States there are numerous localities of common beryl, the most remarkable of which are Acworth, New Hampshire, and Royalston, Massachusetts. One 6-sided prism from Acworth measured 4 feet in length.

BERZELITE.

ramid = $130^\circ 59'$. Cleaves parallel to M. Rarely occurs granular.

H. = 7.5 — 8. G. = 2.68 — 2.74.

Color rich emerald green, light apple-green, passing into light greenish blue, yellow and colorless; lustre vitreous; transparent, sub-translucent; sub-brittle; fracture conchoidal, uneven.

Behavior. A thin splint is rounded on the edges by a strong and continued heat, forming a vesicular glass; the transparent becomes milk-white; forms a colorless bead with borax (smaragd gives a slight greenish tint with both fluxes); mic. salt dissolves it slowly without leaving a skeleton of silica, the piece diminishing much in size, and an opaline bead on cooling; dissolves clear and colorless in soda; cobalt solution scarcely yields a blue color; beryl from Broddbo and Finbo gives traces of tin. Insoluble in acids, but after strong ignition is partially decomposed by sulphuric acid.

Analysis. 1. Beryl from Siberia, by Klaproth; 2. by Du Menil; and 3. by Thomson; 4. from Broddbo by Berzelius; 5. from Fossum by Scheerer; 6. Emerald by Vauquelin; 7. by Klaproth:

$5\frac{1}{2}$ inches across its lateral planes, and weighed 240 lbs.; other localities are Barre, Pearl Hill, and Chesterfield, Massachusetts; Albany, Norwich, Streaked Mountain, Georgetown, in Bowdoinham, Topham, Maine; Wilmot, New Hampshire; Middletown, Haddam, Monroe, Connecticut; Leiperville near Chester, Germantown, &c., Pennsylvania; Dixon's Quarry near Wilmington, Delaware. (*Dana.*)

BERZELINE. *Min.* Minute white crystals. with vitreous lustre on the surface of fracture, translucent; fuses with difficulty to a pale, vesicular glass; gelatinizes with acids. Occurs near La Riccia in the Roman States. It is probably a zeolite. (*Ram.*)

BERZELITE. *Min.* Three minerals have received this name. The mineral analyzed by Kühn is probably a magnesian PHARMACOLITE. The same has also been applied to PETALITE. (See these). We retain the name Berzelite for the lead-ore from Mendiff, which has also been called Mendiffite.

Berzelite. *Syn.* Peritomous Lead-Baryte, *Mohs*; Mendiffite; Kerasite.

Descrip. Cryst. System, Right Rhombic; the

BETULIN.

planes of prism = $102^{\circ}27'$; parallel to which it cleaves; occurs in fibrous or columnar masses, often radiated.

H. = 2.5–3. G. = 7–7.1

Color yellowish or reddish white; subtranslucent, opaque, lustre pearly on planes of cleavage; streak white.

Behavior. Decrepitates, fuses readily, becoming yellower; gives metallic lead and acid vapors; with mic. salt and oxide of copper it gives the reaction of chlorine, readily soluble in nitric acid.

Analysis. By Berzelius.

Oxide of lead.....	90.20	90.13
Chlorohydric acid	6.54	6.84
Carbonic acid....	2.63	1.03
Water	0.63	0.54
Silica	—	1.46
	100	100

Abstracting carbonate of lead, silica and water, it is a basic chloride or oxychloride of lead, $\text{PbCl} + 2\text{PbO}$ or $\text{Pb}_3 \begin{cases} \text{Cl} \\ \text{O}_2 \end{cases}$.

Local. It occurs at the Mendip hills, Somersetshire, on earthy manganese.

BETULIN. See BIRCH.

BEUDANTITE. *Min.* Cryst. System, Hexagonal, occurring only as an obtuse rhombohedron with terminal planes; the angles of the rhom. = $92^{\circ}30'$. H. = 4–4.5. Color black; lustre resinous; in thin splinters translucent, and deep brown; streak, greenish gray; gives only the reaction of oxides of iron and lead, of which it consists. It occurs at Horhausen on the Rhine.

BEZOAR. *Anat.* Rounded concretions from the first stomach of different ruminating animals. They are usually divided into Oriental and Occidental, a division of no importance. The *Oriental Bezoar* is found in the *Capra Aegagrus* and the *Gazelle (Antelope Dorcas)*. They are spherical or oval, from the size of a pea to a diameter of several inches, and consist of thin concentric layers enclosing a central kernel of some foreign substance. They are inodorous and tasteless, almost insoluble in water, alcohol, and muriatic acid, soluble in caustic potassa with a brown color; infusible, evolving an agreeable odor when heated, and burning without residue.

Occidental Bezoar, derived from the lama, &c., resembles the oriental in external characters, gives off less odor by heat, and consists mainly of phosphate of lime and a kind of humus substance. The German bezoar is derived from the chamois, and consists of interlaced vegetable fibres and hair, covered with dried mucus.

It is highly probable that bezoars are very different in composition, containing cholesterin, gall-resin, fatty and coloring matters, &c. Some, indeed, appear to consist almost wholly of a peculiar acid, such as LITHOFELLINIC and BEZOARIC ACIDS.

BEZOARIC ACID. An oriental bezoar examined by Lippowitz was of dark olive-green color, and consisted of a peculiar acid termed by him *Bezoaric acid*. It was dissolved in a cold solution of potassa, from which chlorohy-

BILE.

dric acid precipitated stellate groups of minute yellowish crystals. If the solution be dilute and hot, dilute acid throws down larger but still microscopic prisms pointed at each extremity; but if the solution be strong and hot, the crystals have a form resembling the letter S. The same peculiarities are observable in cold solutions, but the crystals are half the size.

Bezoaric acid dissolves in sulphuric acid with a dark olive-brown color, from which water precipitates it crystallized in the curved form. It dissolves in chlorohydric acid with a beautiful color, resembling that of decomposed uric acid. Fused with potassa, it affords a clear solution with water; the alkaline salts are decomposed by the weakest acids, and even by sal-ammoniac. It appears to contain little or no nitrogen. (Lippowitz in *Ch. Gaz.* March, 1844.) Lippowitz does not point out the difference between it and lithofellinic acid, but from his description the bezoaric dissolves with difficulty in ammonia.

BI, BIN. Prefixes employed to signify two parts of the substance to which the term is prefixed. *Bi* is employed before a consonant, *bin* before a vowel. Thus bicarbonate of potassa consists of 1 eq. potassa and 2 eq. carbonic acid. Other compounds are bitartrate and binoxalate of potassa, binoxide of manganese, bichloride of platinum, &c.

BILE. The liquid secreted by the liver and evacuated through the hepatic duct into the duodenum. When the latter is empty, the orifice of the hepatic duct is closed, and the secreted bile is made to flow back through the duct of the gall-bladder into the latter vesicle, in which it then accumulates until, during digestion, the duodenum is expanded and the bile allowed to flow both from the liver and the gall-bladder through their common duct into the duodenum and mix with the digesting food.

Bile is a yellow or greenish yellow liquid of a bitter and nauseous taste, and of a peculiar disagreeable odor. It always contains in solution a quantity of mucus derived from the gall-bladder, which renders it viscid, and sometimes capable of being drawn into threads. Thenard found the specific gravity of ox-gall to be 1.026. Bile of birds is thinner, and that of fishes thicker. Bile does not coagulate by heat.

The chemical nature of bile has often been the subject of chemical investigation, but with such different results that, although our knowledge in regard to this secretion has been considerably enlarged, we are at present, after more than thirty years laborious investigations by the most eminent chemists in regard to a true understanding of its chemical nature, left at the same point whence we first started.

The property of bile to froth, by shaking, and to decompose, by the addition of acids, with the precipitation of a resinous substance, induced chemists at first to consider it as a soap-like combination. Fourcroy observed the precipitation of mucus by the addition of alcohol, and considered it as albumen. Berzelius, who afterwards (1807) examined the chemical nature of bile, called the resinous substance of the bile, which precipitates by heating it with acids, *Gallenstoff* (biliary matter). He obtained

it by precipitation with sulphuric acid and subsequent removal of this acid from the precipitate by digestion with carbonate of lead or baryta; but it was afterwards proved that the substance thus prepared contained baryta, or oxide of lead in chemical combination. About the same time Thenard separated the bile by precipitation, with neutral and basic acetate of lead, into two different substances, of which he called the one Gall-resin and the other Picromel (*Puces, bitter*, and *μικρ., honey*), from its sweetish and bitterish taste, and his views, that these two substances constituted the main ingredients of bile, prevailed for a long time. Twenty years afterwards (1828), L. Gmelin undertook an extensive examination of the bile. He showed that Thenard's gall-resin and picromel were no pure substances, but that they contained considerable quantities of each other, and that a great portion is not precipitated from the bile by basic acetate of lead, but remains in the solution, and which he, from its sweetish taste, called bile-sugar. Gmelin also proved that Berzelius's gallenstein contained, in combination, baryta or oxide of lead, according to the base used for its preparation, and he continued the idea of the bile being mainly constituted of bile-resin and bile-sugar. He discovered, besides, a number of other substances, as taurin, cholic acid, &c., which he considered as ingredients of the bile.

Ten years later, Demarçay showed that Gmelin's bile-sugar was, by continued boiling with the mineral acids, converted into ammonia, taurin, and gall-resin, and by long-continued boiling with potassa, into cholic acid. It was thus proved, that at least some of these substances obtained in the analysis of bile might be products of decomposition; still it remained probable that, on the other hand, some of them might exist in the bile from spontaneous decomposition before its evacuation. In his general view of the chemical nature of bile, Demarçay returned to the old notion, that the bile mainly consisted of a salt of soda, formed by its combination with a resinous substance, which dissolved with difficulty in water, and precipitated by the addition of acids. This substance he called choleic acid (*acide choléique*). Demarçay denied the existence of Thenard's picromel, or Gmelin's bile-sugar, and considered them both identical with his *acide choléique*.

We will now give the main results of a more recent and complete, but laborious examination of ox-bile by Berzelius, and afterwards add some different views and additions advanced after him by Liebig and others.

According to Berzelius, ox-bile consists principally of a peculiar substance, to which he has given the name of *bilin*, and which possesses a bitter, afterwards sweetish, taste, is soluble in water and anhydrous alcohol, but not in ether nor in concentrated solutions of the carbonated or hydrated alkalies. Besides this, the bile contains mucus, which may be precipitated by alcohol and dilute acids, one or more coloring matters, cholesterin, fat, oleic and margaric acids, extractive, and salts, similar to those contained in the blood. It moreover contains soda in combination with bilin and the fatty

acids. 100 parts of ox-gall yielded 7.162 solid residue, of which the mucus only amounted to 0.251, cholesterin only to 0.001, extractive soluble in alcohol of 0.833, 0.121, extractive insoluble in alcohol, soluble in water 0.433.

It would seem, says Berzelius (*Arseb.* 1842, p. 557), as if the bile only contained the above ingredients in the first moment of its separation, but that it very soon, even in the gall-bladder, commences to undergo decomposition. The bilin is converted into two acids, fellinic and colinic acids, ammonia and taurin. The two first-mentioned acids combine, in the moment of their formation with bilin, to bilifellinic and bilicolinic acids, which are characterized by being precipitated by the mineral acids added in excess from their solution in water, while the bilin, which is not in combination with them remains in solution, and may subsequently be extracted by alcohol after the removal of the acid by carbonate of lime, if it be sulphuric acid, or by carbonate of baryta, if it be nitric acid.

Perfectly sound bile, taken immediately after the death of the animal, and freed from the mucus by the addition of a small portion of sulphuric acid and subsequent filtration, may be mixed with sulphuric acid of 1.6 spec. grav. in all proportions without precipitation of any bilifellinic acid, which proves that the decomposition of bilin has not extended very far. No taurin can be discovered in such fresh bile.

Out of the body this decomposition, on the contrary, takes place rapidly, if the mucus be not separated either by alcohol or an acid, as it acts as a ferment, so that, after the lapse of a few days, the addition of any of the mineral acids will produce a large precipitate of bilifellinic and bilicolinic acids.

Bile, when left to itself, without previous filtration, for one or more weeks, becomes darker, its yellow or yellowish red color changing into green, and it assumes an ammoniacal and putrid smell. In this case it contains different substances. Bilin is still contained in it, but combined with different acids, which precipitate by the addition of even a small quantity of acid, leaving scarcely any bilin in the solution. The precipitate is insoluble in water, like that of bilifellinic and bilicolinic acids. The contained acids are now cholic and fellanic acids, and greater and smaller quantities of fellinic and cholinic acids. The bile now contains quite a considerable quantity of taurin.

The ox-bile of Pharmaceutists (*fel tauri inspissatum*). Obtained by evaporating common ox-gall to the consistence of an extract without previous separation of the mucus, suffers gradually the same decomposition, but it contains another acid besides these, the cholanolic acid.

The acids which thus are formed by the progressive decomposition of the bilin in the bile, are fellinic and cholinic acids, next cholic and fellanic acids, and lastly, cholanolic acid. The four first mentioned form, with bilin, compound acids.

Although boiling with acids accelerates the decomposition of bilin into ammonia, taurin, and fellinic and cholinic acids, as shown by

Demarcay's experiments, the presence of free acid is by no means necessary. The decomposition occurs even with the presence of free alkali, and both in watery as well as in alcoholic solutions, although in the latter much slower. This is also the cause of the great differences in the results of the analyses of the bile and of the number of ingredients which have been found, but do not exist in fresh bile.

In regard to the coloring matter of the bile, it is mostly as prone to decomposition as bilin. The green coloring matter, which Berzelius called biliverdin, but which he afterwards found to be identical with chlorophyll, or the green coloring matter of leaves (see CHLOROPHYLL), does not exist in fresh bile. The color of fresh bile is not green but yellow or reddish yellow, and, like bilin, extremely prone to decomposition, so much so, that it would be extremely difficult of investigation, if it not sometimes accumulated in such quantity as to form a peculiar kind of biliary concretions, which have been investigated by Thenard and L. Gmelin. Berzelius proposes for it the name of *cholepyrrhin* (from *χολη*, bile, and *πυρρος*, orange-yellow). Of its metamorphosis, the green coloring matter of the bile, biliverdin, or chlorophyll is probably a product. Berzelius found, besides, another yellow substance in the bile, which he called *bilifulvin*, but he leaves it undecided whether it exists originally in the bile or it be a product of its decomposition.

We will now give a more detailed description of the above-mentioned substances, according to Berzelius:

1. *Bilin*. It forms the main ingredient of the bile. Berzelius obtained it by evaporating the bile to dryness, pulverizing the dry mass, and extracting free fatty matter by ether. The residue is then dissolved in anhydrous alcohol, which leaves behind mucus, chloride of sodium, and other saline and organic matters insoluble in alcohol, while the main mass of the bile, with oleate and margarate of soda and the coloring matter dissolve. The alcoholic solution is then precipitated with a solution of chloride of barium as long as any precipitate is produced, filtered, and then, in the same way, precipitated by baryta water, by which the solution becomes almost perfectly colorless. The solution is then freed from baryta by a stream of carbonic acid gas, filtered, evaporated to perfect dryness, which may be completed in vacuo, redissolved in anhydrous alcohol, which leaves behind the freshly formed chlorides of barium and sodium, and the alcoholic solution precipitated by sulphuric acid, diluted first with half its weight of water, and afterwards with alcohol, whereby the remaining bases of soda, baryta, and ammonia are precipitated as sulphates. After complete precipitation, the solution is mixed in a retort with freshly precipitated carbonate of lead and distilled, excluding the air as much as possible. After the distillation of most of the alcohol, the solution is separated by filtration from the precipitate; the small quantity of oxide of lead which it contains in solution, precipitated by sulphuretted hydrogen, and the solution evaporated to dryness in a water-bath, and, for complete expulsion of the water, heated in vacuo

to from 212° to 238°. The mass is then again treated with ether, which extracts free fatty acids, and freed from the ether by placing it in vacuo over sulphuric acid. This substance forms then, apparently, a homogeneous mass of an acid character, and constitutes what Berzelius in his earlier examination called *gallenstoff*, but then combined with baryta. It is dissolved in water and digested well with fine oxide of lead, added in small portions, and the solution filtered from the plaster-like mass, evaporated to dryness in a water-bath, and dissolved in anhydrous alcohol, without washing the small residue that remains. Thus a colorless solution is obtained which contains no oxide of lead, is not precipitated by addition of sulphuric acid, and is perfectly neutral to vegetable colors. This solution, evaporated in vacuo over sulphuric acid, leaves the bilin in its perfectly pure state.

Bilin may also be prepared from the precipitate which is obtained by digesting bile with dilute sulphuric acid, by treating it with ether and afterwards with fine oxide of lead, in the above detailed manner. The biliverdin and the fatty acids are then partly dissolved by the ether and partly remain afterwards in combination with the oxide of lead.

Thus obtained, bilin forms a transparent, colorless, or slightly yellowish mass, inodorous, and of a bitterish taste. At a temperature above 212° it swells up and gives off water. It is soluble in all proportions in water and alcohol, but insoluble in ether, by the addition of which, to its alcoholic solution, it precipitates in the form of a magma. It is identical with the bile-sugar of Gmelin. But the crystalline texture in which Gmelin obtained it was due to its content of acetate of soda, with which it occurred so intimately mixed as to render it difficult to distinguish them.

Bilin is not precipitated from its watery solutions by acids, not even by tannin, nor by chlorine passed through its solution, nor by salts of the alkalies, the earths, or the metals; but when mixed with a great excess of the alkalies or their carbonates a semi-liquid combination of bilin with the alkali is separated, which is soluble in anhydrous alcohol.

Bilin is exceedingly prone to decomposition, even in solid form. Acids and heat accelerate the decomposition very much. The mineral acids cause a complete decomposition, and precipitate at the same time several of the products of the decomposition. The organic acids, on the contrary, decompose it only incompletely, and do not cause any precipitate. If bilin be digested for some time in dilute muriatic acid, a yellow oily substance separates, which increases on cooling, and which is the first product of its decomposition. It still contains bilin, but in combination with two acids, fellylinic and colinic acids (see further below, under *Bilifellylinic* and *Bilicolinic acids*), and which are contained in the combination obtained in the preparation of the bilin by digestion with oxide of lead. By continuing the digestion, the bilin is entirely decomposed, the precipitate assumes a resinous character, and contains now only fellylinic and cholic acids and dyslysin (see further below), while the solution contains

ammonia in combination with the chlorohydric acid, and a crystallizable substance called taurin.

2. *Fellinic acid*; 3. *Cholinic acid*; and, 4. *Dyslysin*. These substances are obtained by digesting bilin with chlorohydric acid in the above-mentioned way until the resinous precipitate, when washed with water, does not dissolve in fresh portions of warm water so as to produce a precipitate when added to the original acid solution. The resinous precipitate is then treated with cold alcohol of 0.04, which dissolves fellinic and colinic acids, and leaves behind the dyslysin.

Dyslysin (from *δυσ*, *difficulty*, and *λυσις*, *solution*) is thus obtained as a resinous substance, sparingly soluble in boiling alcohol, even when anhydrous. The latter deposits it by spontaneous evaporation as a white earthy precipitate, insoluble in the alkaline carbonates.

Fellinic (Fel, bile) and *Cholinic* (χολη, bile) acids are contained in the alcoholic solution from the dyslysin. They are best separated by adding to the solution several times its bulk of water and leaving it to rest, by which it deposits a precipitate, which, in preference, contains cholinic acid, while the solution retains most of the fellinic acid. The precipitate is treated with a solution of carbonate of ammonia, which dissolves fellinic acid, while cholinic acid remains as an acid salt in combination with ammonia in the state of a soft, flocculent precipitate, resembling coagulated albumen. The solution containing fellinic acid, combined with ammonia, is evaporated to dryness, and forms a yellowish, transparent, hard mass, of a bitter taste, which, by cautious solution in water, still leaves some residue of supercholine of ammonia. By the addition of chlorohydric acid to the solution, fellinic acid separates as white flocks, which collect and adhere to the vessel, and become hard on drying, if they contain bilin, otherwise they remain pulverulent.

Fellinic acid is without odor, has a bitter taste, fuses above 212° to a clear mass, giving off, at the same time, a great deal of water, and remaining, after cooling, hard, colorless, and transparent. By greater heat, it swells up, takes fire, and burns like a resin, leaving a porous coal. Boiled in water, it melts into a white mass and dissolves to a certain extent, separating again on evaporation in limpid drops. The solution in water reddens litmus-paper, and has a faint bitterish taste. It is easily soluble in alcohol, even when dilute, and the solution has a pure bitter taste like bile. It is more soluble in ether than in water, but less than in alcohol. Both from alcohol and water it separates on evaporation in drops.

With the *alkalies*, fellinic acid forms salts, which are soluble in water and alcohol, but insoluble in ether. Excess of the caustic or carbonated alkalies precipitate them completely from their solution in a plaster-like mass. *Fellinate of baryta* is obtained by precipitation of one of its alkaline salts by chloride of barium. It is plaster-like, and melts into a transparent mass by heating; is perceptibly soluble in hot water and dissolves easily in alcohol. The salt of *lead* is similar to it.

Cholinic acid is obtained by treating in the same way the obtained salt of ammonia with chlorohydric acid, by which it is converted into white flocks, which are washed, and, on drying, become a brown, hard, and easily pulverizable mass. It melts easily; is insoluble in water, but dissolves easily in alcohol; is sparingly soluble in ether. With the alkaline carbonates, it forms combinations resembling, in appearance, glue, and being but very slightly soluble in water, but soluble in alcohol. Caustic alkalies show little reaction on fused cholinic acid, but added to its alcoholic solution, it forms combinations soluble both in water and alcohol. The salt of baryta does not agglutinate.

5. *Bilifellinic* and 6. *Bilicholinic acids*. These two acids are contained in the plaster-like precipitate obtained in the preparation of the bilin (see above) by digestion with oxide of lead. This precipitate is washed with water, and digested with an alkaline carbonate for the separation of the oxide of lead, and filtered. A solution is thus obtained resembling bile in taste and odor. If this solution be mixed with sulphuric acid as long as any precipitation takes place, the plaster-like precipitate washed with dilute sulphuric acid and then treated repeatedly with pure ether, a thick liquid separates, while the ethereal solution on evaporation leaves a brownish residue, soluble in alcohol, and by treatment with carbonate of ammonia yields fellinate and choline of ammonia.

The syrupy liquid separated from the ethereal solution may be mixed with water in all proportions, and has a bitter taste like bile. Treated with oxide of lead it forms again a plaster-like precipitate, while bilin remains in the solution. By repeated treatment of the former, exactly in the same way as before, with carbonate of soda, sulphuric acid, and ether, the whole may thus be converted into bilin and fellinic and cholinic acids. The rationale of this is, that bilin combines with fellinic, and probably also with cholinic, acid in two proportions, of which the one is formed by treatment with a base in excess, with which it forms an insoluble compound. A portion of bilin is then liberated and remains in the solution with a small portion of the basic lead-salt, which is separated by evaporation to dryness, and treatment with alcohol. If, then, the combination of the base with these acids containing less bilin be decomposed by sulphuric acid, and the separated compound treated with ether, the latter takes up a portion, perhaps half, of the acids, and leaves the other portion in combination with the whole of the bilin. It seems somewhat uncertain whether cholinic acid combines with bilin, or whether it merely follows, mechanically, the fellinic acid in these reactions. Berzelius suggests that the bilifellinic acid, with both proportions of bilin, might be combined to salts with bases, of which those of the bilifellinic acid, with the greatest proportion of bilin, are soluble in water, and perhaps contained in the gall.

7. *Biliverdin* (*Chlorophyll*). Ger. Gallengrün. Obtained by precipitating an alcoholic solution of inspissated bile by a solution of chloride of

barium added in small portions as long as any precipitate is formed, which is separated by filtration, and washed first with alcohol and afterwards with water. This precipitate of biliverdin with baryta is not obtained from a watery solution on account of its solubility in a watery solution of bilin. The above precipitate, while yet moist, is then treated with dilute chlorohydric acid, which extracts the baryta, leaving biliverdin behind; the latter is freed from adhering fatty matter by ether, which also dissolves a small portion of biliverdin. The remaining precipitate is then treated with cold anhydrous alcohol, which dissolves the biliverdin with a greenish brown color, and deposits it again on evaporation. The residue from the solution in alcohol is soluble in alkaline carbonates and is a combination of biliverdin with an animal matter.

Biliverdin is of a greenish brown color, pulverulent, without taste, and inodorous. Does not melt by heat, and yields no ammoniacal products. Insoluble in water, soluble with green color in caustic and carbonated alkalies, and again precipitable by the addition of acids. The solution in carbonate of ammonia loses its ammonia by evaporation. The tint of its green color varies. It dissolves in alcohol; addition of water does not precipitate it. The concentrated alcoholic solution is almost red by transmitted light. Soluble but sparingly in ether, mostly with a red color. Combines with fat, to which, as well as to other animal matters, it is capable of imparting a green color, even in very small quantities. Soluble in sulphuric and chlorohydric acids with a beautiful green, and in acetic acid with a red color. Nitric acid, like the other acids, precipitates biliverdin, from its solution in alkalies, but added in excess destroys it. *Biliverdin is identical with Chlorophyll*, or the green coloring matter of leaves. In the gall of carnivorous animals it seems to have different properties, or to be combined with some other coloring matter.

8. Sometimes a *yellow coloring matter* occurs suspended in the bile and gives rise to a peculiar variety of biliary concretions. Thénard, who first observed this substance in human bile, called it *matière jaune de la bile*, and showed its identity with gallstones from oxen and with one obtained from an elephant.

According to Gmelin, who examined a gallstone from an ox, the latter could easily be reduced to a reddish brown powder. Boiling alcohol extracted a small portion of fat and assumed a yellow color. Caustic ammonia dissolved only a small portion. Caustic potassa proved the best solvent. The potassic solution had a yellow color, and became greenish brown by absorption of oxygen from the air. With an excess of nitric acid it shows a reaction which is characteristic of it. If too great an amount of acid be avoided, and the whole stirred at the same time, the liquid becomes at first green, then blue, violet, and at last red, all in the course of a few minutes. After some time the red color also disappears, the liquid becomes yellow and the coloring substance is now entirely changed. The presence of only a very minute quantity of coloring matter is sufficient to produce this reaction

in a very perceptible degree, and it takes place not only with bile, but also with serum, chyle, urine, and other fluids as soon as they, in jaundice, assume a yellow color, and affords therefore the surest test of the presence of bile, or at least its coloring matter. Addition of chlorohydric acid to the potassic solution precipitates it in dark green flocks, which, after washing and drying, are again soluble in nitric acid with a red color, which, however, soon becomes yellow; they are also soluble in ammonia and potassa. The cause of the change in the color of bile from yellow into brown and green seems to depend on the oxidation of the coloring matter of the bile, whereby it passes from yellow into green and becomes easier soluble in water. Bile mixed with an acid, and left exposed to the air for several days, becomes perfectly green, with absorption of oxygen; but, if the air be perfectly excluded, this change does not take place. Gmelin mixed dog-bile, which is yellowish brown, with chlorohydric acid in a sealed tube over mercury. Thus protected from the influence of the air, the color remained unaltered, but on admission of oxygen, it absorbed half of its volume of the latter gas and became green, beginning from the surface.

Biliverdin is therefore most probably a product of the decomposition of this yellow coloring substance, for which Berzelius proposes the name of *Cholepyrrhin* (πύρρις, yellow). Biliverdin of oxgall does not exhibit this change of color, nor that produced by nitric acid. Chlorine produces the same change of color as nitric acid, but less distinctly. This change of colors by nitric acid is not only produced with bile from carnivorous animals, but also from birds, fishes, and reptiles, although the color of the bile varies not only in different animals, but even in different individuals of the same animal.

9. *Bilifulvin*. This name is given by Berzelius to a crystallizable reddish yellow substance which is contained in the precipitate obtained by barytic water after precipitation of the alcoholic solution of oxgall by chloride of barium (see under *Bilin*). The precipitate is first washed with alcohol, then dissolved in water, and the watery solution precipitated by acetate of lead. The precipitate is washed, decomposed by sulphuretted hydrogen, and the filtered solution evaporated to an extract, dissolved in alcohol, and left to spontaneous evaporation, by which bilifulvin separates in small reddish yellow crystals; these are an acid double salt of soda and lime, with bilifulvinic acid, which forms a pale yellow pulverulent mass, insoluble in water and alcohol.

10. *Mucus*. The bile contains much mucus, partly dissolved, but for the most part in suspension, as a slimy mass, which is the cause of its property of drawing into threads; this is not the case after its filtration, by which the suspended mucus remains on the filter. But the filtered bile contains also mucus in solution, which may be precipitated by acetic and other acids, and by alcohol. If precipitated by acid it retains a portion of this in chemical combination. The mucus remaining on the filter may likewise be combined with acids.

Carbonated alkalies extract the acid, without restoring the slimy appearance. By a small portion of caustic potassa or soda it again becomes slimy, and may be drawn into threads; by addition of more alkali it becomes thin. When precipitated by acetic acid from the bile it often retains a portion of biliverdin, which may be extracted by carbonate of ammonia. Alcohol does not precipitate it in its slimy state, but this is resumed on washing with water, unless when precipitated by alcohol of great strength. The mucus becomes yellow and transparent on drying, after which it again swells up in water, but does not become slimy. By the treatment of inspissated bile with alcohol, the mucus remains with other residuary substances, but in a coagulated condition, and cannot be recognised. In its moist state it soon becomes putrid, which does not happen with the other ingredients of the bile.

Gmelin found that by boiling washed mucus with water, evaporating the filtered solution to dryness, and treating it with boiling alcohol, the latter dissolved a substance which partly precipitated on cooling, and partly separated by evaporation of the alcohol, as a yellowish transparent pellicle. This substance Gmelin called *casein*. The residue left by the alcohol he considered as identical with *salivary matter* or *Ptyalin* (see *SALIVA*), but they are evidently products from the decomposition of the mucus by boiling.

11. *Fat*. The bile contains several fatty matters, as common *fat* (not saponified), and as *fatty acids*, in combination with soda, *cholesterin*, and probably *serolin* and other *fatty matters of the blood*. If bile be evaporated to dryness and treated with ether, the latter dissolves common fat, serolin, cholesterin, and a portion of the fatty acids, the greater part of which remains in combination with alkali. The ethereal solution deposits, on evaporation, cholesterin in foliated crystals mixed with a liquid fat, which may be extracted by weak cold alcohol. Stronger cold alcohol dissolves the cholesterin and leaves a pulverulent fat, which seems to be serolin. The alcohol deposits the cholesterin in crystals by spontaneous evaporation.

Cholesterin or *Gall-fat*. We have already mentioned that cholesterin only forms $\frac{1}{1000}$ part of common ox-bile. The greater part of biliary concretions are often formed of this substance. See *CHOLESTERIN*.

12. *Salts of the Bile*. These are chloride of sodium, phosphate, lactate, oleate, margarate, and perhaps also cholate of potassa, soda, and ammonia; soda exists also in combination with bilin and bilifellinic acid; some phosphate of lime is also contained in it. Of these, chloride of sodium and the phosphates of soda and lime remain undissolved by the treatment of dry bile with anhydrous alcohol. Carbonate of ammonia is generally also contained in inspissated bile, as kept for medicinal purposes.

Action of Acids on Bile. By the addition of acids to bile the mucus is first precipitated. After the separation of the latter, chlorohydric or sulphuric acid may be added in any quantity without producing any precipitate. In the

same way the alcoholic extract of bile may be dissolved in sulphuric acid diluted with 4 to 5 times its weight of water, and mixed with water in all proportions without the separation of any precipitate. But as soon as the solution is heated, it deposits a thick green liquid at the bottom, which, by continued digestion, becomes more solid. If the liquid be then left for some hours to cool, a viscid mass, which is liquid while hot, is floating on the top, and consists of fat, fatty acids, and cholesterin. The deposit at the bottom is bilifellinic acid, and contains also a chemical combination of bilin, with sulphuric acid. The bilin, by digestion with the acid, has been converted into bilifellinic acid, which is only sparingly soluble in dilute acid, and therefore precipitates. This precipitate constitutes Demarçay's *acide choleique*. By continued digestion the bilin, which is combined with sulphuric acid, is first decomposed, then the bilin of the resinous acids, and at last these only (fellinic and cholinic acids and dyslysin) remain mixed with some fatty acids and biliverdin. Chlorohydric acid produces exactly similar results.

The soluble products which are formed at the same time by this decomposition of the bilin by acids, and which remain in the solution, are *ammonia*, which combines with the acid, and *taurin*.

13. *Taurin* (from *taurus*, $\alpha\tau$) discovered by Gmelin, and by him at first called gall-asparagin, from its resemblance to asparagin. Its occurrence in perfectly fresh bile is uncertain.

Preparation. Fresh concentrated bile is freed from mucus by chlorohydric acid, filtered, and then boiled with chlorohydric acid till perfect decomposition of the bilin. The resinous precipitate is then separated and the acid solution concentrated, by which chloride of sodium separates. The solution is then mixed with 4 to 5 times its weight of hot alcohol, and left to cool, by which the taurin separates in radiated crystals, which are washed with alcohol. The acid solution may also be evaporated to dryness in a water-bath and the chloride of sodium extracted by alcohol of 0.86 spec. grav. The remaining taurin is then dissolved in the least possible quantity of boiling water, from which it crystallizes on cooling.

Taurin crystallizes in colorless, transparent regular six-sided prisms, terminated by four or six-sided pyramids, of a sharp taste, without admixture of sweet or bitter; permanent in the air, even when heated to 212°. It is perfectly neutral. By a higher temp. it melts to a thick liquid, puffs up, and leaves a charcoal, which is easily incinerated. By the dry distillation, it yields oil and an acid-water, which contains ammonia and turns a solution of salts of iron red. At 54° it requires 15½ pts. of water for its solution; but in boiling water it is considerably more soluble, and crystallizes from it on cooling. Alcohol of 0.835 only dissolves $\frac{1}{10}$; almost insoluble in absolute alcohol. Cold nitric acid dissolves it without alteration. Its solution in water is not precipitated by chlorohydric acid, potassa, ammonia, alum, chloride of tin, sulphate of copper, nitrate of black oxide of mercury, or nitrate of silver.

Composition. Taurin has been analyzed by

Demarçay and by Dumas, with corresponding results. It consists of

	Atoms.	In 100 parts.
Carbon	4	19.48
Hydrogen.....	7	5.57
Nitrogen.....	1	11.27
Oxygen.....	10	63.68

Its great content of oxygen is remarkable on account of its neutral character.

Action of alkalis on Bile. Demarçay has shown that by boiling a solution of the alcoholic extract of bile with caustic potassa as long as ammoniacal vapors are given off, replacing the evaporated water, from time to time; the greatest portion of the bilin is converted into *cholic acid*.

14. *Cholic acid.* Discovered by Gmelin. *Preparation.* Berzelius prescribes to precipitate the bile by basic acetate of lead, which precipitates all foreign matters, leaving only bilin in the solution, to filter and precipitate the lead from the filtered solution by carbonate of potassa, and then to boil it with an excess of caustic potassa or soda as long as ammoniacal vapors are given off. The solution is then concentrated till the cholate of potassa has precipitated from the solution, which, after cooling, is poured off. The cholate of potassa is then dissolved in water, and precipitated by acetic or chlorohydric acid. The cholic acid separates thus in white flocks, which soon become crystalline, and may easily be washed.

Prop. Cholic acid forms, after drying, a coherent shining mass, consisting of minute crystals of a sweetish and acrid taste. It melts by heat and burns with a smoky flame. By the dry distillation it yields a thick empyreumatic oil and an ammoniacal liquor (*Gmelin*). It is only sparingly soluble in cold water, more so in boiling; easily soluble in alcohol; soluble in sulphuric acid, from which it is again precipitated by water. It expels carbonic acid, with effervescence, from the carbonates.

According to Dumas, cholic acid does not contain nitrogen, consisting of

	In 100 pts.	Atoms.	By calculation.
Carbon.....	68.5	42	68.8
Hydrogen...	9.7	36	9.6
Oxygen.....	21.8	10	21.6

The salts of cholic acid are generally soluble, and have a sweet taste. *Cholate of soda* forms a crystalline mass permanent in the air and easily soluble in water. *Cholate of ammonia* becomes acid on evaporation and leaves behind a colorless, transparent, gum-like mass, easily soluble in water.

Decomposition of Bile by keeping. Bile has a great tendency to putrefy, caused by its content of mucus, for it does not take place after its separation.

The *Fel tauri inspissatum* of pharmacists, made by evaporating ox-bile in a water-bath to an extract, undergoes also a change by keeping, which seems to be different from that effected by acids. Berzelius, who examined a specimen of it, found, besides the usual products of the decomposition of the bilin, two new acids, which he called:

15. *Cholanin*, and, 16. *Fellinic acids*. These

acids were obtained in the following way:

Extract of bile, 8 months old, and yielding ammoniacal vapors by the approach of a glass rod, moistened with nitric acid, was completely dried in a water-bath, treated with ether, dissolved in alcohol, and precipitated by chloride of barium and barytic water for the separation of the coloring matters, as described under bilin; the alcohol distilled off, and the remaining extract then dissolved in water and precipitated by acetic acid, which produces an abundant plaster-like precipitate, leaving only a small amount of bilin in solution. The precipitate is dissolved in ammonia, evaporated to the consistence of honey, and then diluted with 100 times its volume of water and boiled down to $\frac{1}{4}$ of its volume, by which a white precipitate is obtained, which is separated by filtration, dissolved in ammonia, precipitated by chloride of barium, and the white precipitate obtained washed with boiling water, decomposed by carbonate of soda, and the filtered solution supersaturated with chlorohydric acid, which precipitates cholanin acid in white flocks.

Cholanin acid forms a white earthy powder, without taste, and inodorous, melts at a temp. considerably above 212° , and congeals to a white transparent mass. It burns like a resin. Boiled in water it does not agglutinate, and dissolves only very sparingly. Sparingly soluble in cold, easily in hot alcohol, which, on cooling, deposits a small portion crystalline. The rest deposits, on evaporation, as a colorless, transparent, resinous mass. It is not much soluble in ether, from which it deposits crystalline by slow evaporation.

It is a feeble acid, expels carbonic acid from the alkaline carbonates, and forms with them colorless, gum-like salts, soluble in water and alcohol, and insoluble in concentrated solutions of the alkaline carbonates themselves. Its salt with *ammonia*, is decomposed by boiling, and the precipitate contains some ammonia. The salt of *baryta* is earthy, insoluble in water, only sparingly soluble in alcohol, and is decomposed, in contact with it, by carbonic acid gas, into carbonate of baryta and an acid salt, which remains in solution. Boiling with chlorohydric acid, decomposes cholanin acid.

Fellanic acid is contained in the solution, after the precipitation of the cholanin acid, by dilution with water and boiling. The solution is further concentrated and precipitated by chlorohydric acid; the plaster-like precipitate treated first with ether and then water, which leaves the fellanic acid as a white powder.

Fellanic acid, when precipitated by acids from a solution of one of its salts, forms white flocks, which melt by heat into a clear transparent liquid, solidifying, on cooling, to a semi-transparent mass. After drying, it forms a white pulverulent mass, without taste, and inodorous. By dry distillation, it is mostly converted into an acid oil. It is sparingly soluble in cold water, more so in hot, easily soluble in alcohol, from which it crystallizes by slow evaporation; slightly soluble in ether, crystallizing in needles by slow evaporation.

It expels carbonic acid from the alkaline carbonates, combining with them to salts, which are not precipitated by an excess of the car-

bonates, and forming a transparent, gum-like mass. The salt of *ammonia* dissolves again in water after evaporation to dryness in a water-bath. The salt of *baryta* dissolves with difficulty in water, and crystallizes, on cooling, in feathery crystals. From its alcoholic solution it may be obtained in regular crystals.

Frequent use being still made of several names given by Thénard, Gmelin, and Demarçay to substances, which they obtained by certain methods, and which they considered as pure substances and ingredients of the gall, the following will give a comparison between these substances and those of Berzelius treated of in the foregoing.

Thénard's *Resine de la bile*, as obtained by him, was a mixture of bilifellinic and bilicholinic with fatty acids and biliverdin. Gmelin showed that it contained bilin (bile sugar).

Gmelin's *Bile-resin* was the product of the complete decomposition of bilin, and consisted therefore of a mixture of fellinic and cholinic acids and dyslysin, the same as Demarçay's choloidic acid.

Thénard's *Picromel* consisted mostly of bilifellinic and bilicholinic acid mixed with a small portion of the fatty acids.

Gmelin's *bile-sugar* is identical with bilin, but mixed with acetate of soda. The fine crystalline state in which he obtained it was due to this substance so intimately mixed with it, that he considered it to be bilin.

Demarçay's *Choleic acid* (*Acide choleique*).—Demarçay prescribes for its preparation either, 1. to dissolve alcoholic extract of bile in 100 pts. of water, add 1 pt. of sulphuric acid diluted with 10 pts. of water, and evaporate the solution

for several hours till the appearance of oily drops on the surface. The solution is then allowed to cool, the oily substance removed, the sediment at the bottom removed from the solution, which, by further evaporation to $\frac{1}{4}$ of its volume, yields a new portion of it. These sediments are washed with small portions of cold water, dissolved in alcohol, freed from a content of sulphuric acid by barytic water, filtered, and, after concentration to syrupy consistence, shaken with some ether for the removal of fatty acids, and then further evaporated; or, 2. alcoholic extract of bile is dissolved in water precipitated by neutral acetate of lead, while the liberated acetic acid is repeatedly saturated by caustic ammonia. The plaster-like precipitate is washed with water and treated with boiling alcohol, and the alcoholic solution freed from lead by sulphuretted hydrogen, filtered, and after evaporation to syrupy consistence, shaken with ether for the removal of fatty acids, and then further evaporated and the desiccation completed in vacuo at 248°. For reasons previously stated, neither of these methods is capable of yielding products always exactly similar. By the last process bilifellinic acid would be obtained, but the shaking with ether may abstract various proportions of fellinic and cholinic acids. The description given by Demarçay corresponds almost entirely with bilifellinic acid, but shows also the admixture of an excess of the resinous acids (fellinic and cholinic), since bilifellinic acid is not precipitated by acetic acid and is easily dissolved by acetates of potassa and soda. The analyses of Demarçay and Dumas yielded the following results:

	Demarçay.	Dumas.	Atoms.	By calculation.
Carbon	63.71	63.5	42	63.7
Hydrogen	8.82	9.3	36	8.9
Nitrogen	3.26	3.3	1	3.5
Oxygen	24.22	23.9	12	23.9

Demarçay's *choloidic acid* (*acide cholôidique*). This name Demarçay gave to the resinous precipitate of fellinic and cholinic acids and dys-

lysin, which remains after the completed decomposition of bilin by the action of acids on bile. The analyses of Demarçay and Dumas yielded:

	Demarçay.	Dumas.	Atoms.	By calculation.
Carbon	73.16	73.3	38	73.0
Hydrogen	9.48	9.7	30	9.4
Oxygen	17.36	17.0	7	17.6

The close agreement of these analyses can only be explained on the supposition that the above acids always are produced in the same relative proportion from the decomposition of bilin.

Gmelin's *Gliadin* seems to be dyslysin.

Analysis of Bile. According to Berzelius, the analysis of bile may be performed as detailed under bilin and the subsequent ingredients of the bile. Another method is to precipitate the mucus by the addition of a small portion of dilute acetic acid, just so much as is sufficient for this purpose, or by mixing it with double its volume of alcohol. The solution is then filtered and mixed with neutral acetate of lead, by which a small precipitate is obtained of biliverdin, combined with oxide of lead and oleate and margarate of lead. The solution is then precipitated with basic acetate of lead, which produces a white or yellowish plaster-like precipitate, of the same composition as formerly

mentioned (dyslysin, bilifellinic, and bilicholinic acids, see under these), and containing, besides, basic chloride of lead and all the other acids contained in the bile, and precipitated in combination with oxide of lead in excess. The solution then contains only bilin, which is not precipitated by basic acetate of lead, even by the addition of caustic ammonia. The plaster-like precipitate is treated, as prescribed above, with carbonate of soda, sulphuric acid, and ether, &c. (See under Bilifellinic acid.) The residue left by the ether on evaporation is, however, glutinous, on account of an admixture of fatty acids. In the present state of our knowledge, besides the uncertainty and difficulty attending it, but little practical use could be expected from a quantitative determination of the different ingredients of the bile.

According to Liebig, and after him Thayer and Schlosser, bile, when freed from mucus,

coloring matter and fat, is a compound of soda with only one homogeneous nitrogenized substance, which he calls choleic acid (gall-acid, Gallensaure), and which he considers identical in composition with Demargay's choleic acid, and Berzelius's bilifellinic acid, and which, by Theyer and Schlosser, has been called bilic acid. This substance is, according to him, entirely precipitated by basic acetate of lead, and he asserts that Berzelius's bilin is nothing else than this same substance, of which a certain portion remains in solution after precipitation by basic acetate of lead, on account of its solubility in acetate of lead and soda, and that bilin possesses no property which distinguishes it from pure biliary substance. In order to obtain bile in a purified state, or freed from mucus, coloring matter, and fat, fresh ox-gall is strained through linen, and inspissated by evaporation in a water-bath, and then treated with alcohol in the cold, and the biliary mucus separated by filtration. The coloring matter is then removed from the alcoholic solution by precipitation with barytic water, avoiding carefully an excess, or still better by digestion with bone-black for twelve hours at ordinary temperatures, being frequently shaken, after which it is filtered, the alcohol distilled off from the colorless liquid, and the syrupy residue repeatedly agitated with ether until this removes nothing more, and finally dried in a water-bath.

Thus purified and dried, bile forms a solid mass, resembling gum arabic, which may be reduced to a powder, and dissolves without residue to a clear solution in water and anhydrous alcohol, but not in ether, which precipitates it from its alcoholic solution as a magma

From its aqueous solution it separates by the addition of hydrate of potassa as a thick syrup. Acetic and oxalic acids cause no change in its aqueous solution; but the addition of a mineral acid produces immediately a milkiness, and after some time a syrupy liquid separates. Acetate of lead and nitrate of silver also produce precipitates in its aqueous solution. A solution of purified gall is thrown down entirely by the addition of tri-basic acetate of lead, so that only a very small quantity of organic matter remains in solution; an excess of the acetate redissolves a portion of the precipitate. An alcoholic solution of pure gall is not precipitated by neutral acetate of lead; but basic acetate of lead produces a plaster-like precipitate, which dissolves on the addition of neutral acetate of lead.

By precipitation of the aqueous solution with neutral acetate of lead, the liquid at the same time acquires an acid reaction. If acetic acid be previously added, no precipitation takes place. The acid, therefore, which is set free prevents further precipitation, and if it be neutralized by an alkali, the neutral acetate produces a fresh precipitate, and the liquid again becomes acid. After precipitation by neutral acetate of lead, a fresh precipitate is produced by the further addition of subacetate of lead, but a considerable portion of the biliary matter (choleic acid, *Liebig*) remains in solution, on account of its solubility in the excess of the neutral acetates.

The composition of pure gall, purified from mucus, coloring matters, and fat (as prescribed above), *Liebig* represents by the following table. (*An. der Ch. u. Ph.* xlvii. 3, 1843.)

	Kemp.		Enderlin.		Theyer and Schlosser.		
Carbon	58.46	58.46	59.9	58.28	58.00	58.49	59.48
Hydrogen	8.30	8.81	8.9	9.20	8.09	8.48	8.47
Nitrogen	3.70	25.76					
Oxygen	22.64						
Soda	6.53	6.53					
Chloride of sodium....	0.37	0.54					

That the soda does not exist as carbonate, but is in actual combination with the electro-negative substance of the bile, (choleic acid, *Liebig*, bilic acid, *Th.* and *S.*) follows from the fact that gall, when fresh, nearly always exhibits a neutral reaction. The composition of this biliary matter, his *choleic acid* (*Gallensaure*) and Theyer and Schlosser's *bilic acid*, he represents, after deducting the fixed ingredients from the above composition, by the following:

Carbon	63.7
Hydrogen.....	8.9
Nitrogen.....	3.9
Oxygen.....	23.5

From which he concludes it to be identical, at least in composition, with Demargay's choleic acid (see this above), and he recommends the following method for obtaining it in its free state. 8 pts. dry purified bile are dissolved in alcohol and mixed with one part of effloresced oxalic acid, heated to ebullition, and subsequently left to rest for 10 to 12 hours, whereby the soda separates as oxalate of soda. The solution is then filtered, diluted with some

water, and digested with carbonate of lead for the removal of oxalic acid. A trace of lead in the solution may afterwards be removed by sulphuretted hydrogen. The solution is then evaporated in a water-bath to dryness. Instead of oxalic acid, the dry purified bile may be dissolved in anhydrous alcohol and the solution saturated with chlorohydric acid gas, by which the soda separates as chloride of sodium. The solution is then concentrated in a water-bath and mixed with water, by which it separates into two portions an aqueous acid solution containing chlorohydric acid and a viscous portion formed by the acid in question, which is insoluble in dilute mineral acids, and is removed, dissolved in alcohol, and treated with finely pulverized oxide of lead till the solution indicates a content of the latter. It is then filtered, freed from oxide of lead by sulphuretted hydrogen, and evaporated as before.

It thus forms a colorless mass of a resinous nature, easily pulverizable, and of an intensely bitter taste. It attracts moisture from the atmosphere, and dissolves easily in alcohol and water, but not in ether. The aqueous solution

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remains clear for several days, has a strong acid reaction, and is not precipitated by acetic acid. Addition of dilute chlorohydric or sulphuric acid produces a turbidness, and precipitates the acid as oily drops, which again disappear by an excess of the acid. Heated on platinum foil, the dry acid is decomposed, burns with a smoky flame, and leaves a porous coal, which, on incineration, yields no ashes.

If a solution of this acid be re-combined with soda, it again acquires most of the properties of gall. One main difference, however, remains, for this restored bile is precipitated immediately by mineral acids, while these may be mixed with fresh bile without any precipitation, until heat be applied.

This latter fact seems, in reality, to point out an essential difference between this acid and the electro-negative ingredient as it exists in the bile. Subsequent analyses of G. Kemp seem also to prove that bile is by no means homogeneous, and that at all events its composition is not identical with Demargay's or Liebig's choleic acid, for the organic portion of the bile of some animals (the tiger) he found to contain as much as 69 per cent. of carbon,

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while the organic body, precipitated from this bile by basic acetate of lead, contained only 62 per cent. of carbon.

Liebig also asserts that Berzelius's fellinic acid and several other of his substances are not pure bodies, but derive their main differences from the admixture of biliary matter in its different stages of decomposition.

Bile of different Animals. Human bile is neutral, of a deep brownish yellow color, without the olive tint which characterizes ox-bile. The coloring matter of human bile produces the characteristic change of colors with nitric acid. Frommherz and Gugert give the following as ingredients of human bile, biliary mucus, coloring matter, salivary matter (?), casein (?), extractive, cholesterin, bile-sugar, bile-resin, cholate, margarate, carbonate, phosphate and sulphate of soda, with a minute portion of potassa, phosphate, sulphate, and carbonate of lime. For its ultimate composition, see table below.

According to Kemp, bile of carnivorous animals contains no chloride of sodium, but only soda. The following table gives the result of the ultimate analysis of bile from different animals, performed by him:

Inorganic Portion.								
	Ox-bile.		Human bile.		Tiger's bile.	Leopard's bile.		
Soda.....	6.53		6.6		5.2	4.6		
Chloride of sodium	0.37		1.87					
Organic Portion.								
	Ox-bile.		Human bile.		Tiger's bile.		Leopard's bile.	
	1.	2.	1.	2.	*Lead salt.		1.	2.
Carbon.....	64.60	64.85	68.4	68.3	69.6	62.1	59.8	59.5
Hydrogen	9.62	9.40	10.13	10.00	11.8	9.3	9.49	10.0
Nitrogen	3.40	3.40	3.44	3.50	6.0		4.60	4.60
Oxygen	22.38	22.35	18.03	18.2	12.60		26.11	25.90
	100.00	100.00	100.00	100.00	100.00		100.00	100.00

Bile of *birds* varies, according to Gmelin and Tiedeman, in different individuals of the same species, being sometimes of a bluish, at others of an emerald green color, and sometimes exhibiting the color of verdigris. Their bile contains the same inorganic substances as are found in ox-bile. Chicken's bile is precipitated by sulphuric and chlorohydric acids, but the precipitate redissolves in an excess of the acid. The solution by sulphuric acid exhibits a green color, but passes gradually into a red. From the same bile potassa precipitates a green substance, which agglutinates and adheres to the sides of the vessel, but dissolves again in pure water, and deserves further examination. (See under bile of fishes.)

The bile of several *serpents* is grass green. Berzelius examined the bile of *Python bivittatus* with the following results. Its color was dark greenish. It contained, as a principal ingredient, bilin, identical with that in the bile of mammalia, but scarcely any bilifellinic acid, yielding with basic acetate of lead only a very slight precipitate. The bilin is also decomposed by acid with much greater difficulty than that of ox-bile. The coloring matter, with which it occurs combined, resembles that of other animals, being but slightly soluble in water, but abundantly in

a solution of bilin. It contained, besides these, a small quantity of a crystallizable biliary substance, precipitable by carbonate of potassa, and resembling that found in the bile of fishes.

Berzelius found also a substance resembling salivary matter, together with another sparingly soluble in cold, but easily in boiling water. This bile contained no biliary mucus, but instead of it a peculiar animal matter; and also fatty acids and the usual salts.

Bile of *fishes* is generally more concentrated than in warm-blooded animals. The bile of *Cyprinus leuciscus*, *alburnus*, and *barbus*, of *Salmo fario* (trout) and *Esox lucius* (pike), have been examined by Gmelin. The inorganic salts consisted principally of sulphate of soda and lime, with traces of ammonia, and, on incineration, phosphate and carbonate of lime and magnesia. The coloring matter varies both in quantity and tint. The bile from *Cyprinus barbus* contained 19.3 per cent., and that of *C. leuciscus* 14.3 per cent. solid matter. The biliary matter of the genus *Cyprinus* is peculiar, possessing but little color, but crystallizing

* Obtained by precipitating the bile by basic acetate of lead.

BILIARY CONCRETIONS.

easily, and imparting a crystalline appearance to the residue of the bile on evaporation. It may be precipitated from the bile by caustic potassa, by the addition of which it coagulates to a greenish granular mass, which may be pressed, washed with a weak solution of potassa, again pressed, and dissolved in alcohol, and remains then, on evaporation, as a colorless crystallized mass. It is not improbable that in this state it contains potassa in chemical combination. Its aqueous solution is precipitated by acids, but re-dissolves by an excess. It is not precipitated by chloride of iron or an infusion of nut-galls. The bile of the pike and other fishes does not become crystalline on evaporation, and is not precipitated by caustic potassa.

Bile in diseases. In that affection of the liver in which the latter is converted into fat, the bile loses entirely its usual character and becomes albuminous. In some cases diseased bile has been found poisonous.

In jaundice bile passes over in nearly all secretions, in which the coloring matter may be discovered by the stain it imparts to paper or linen, and by its peculiar reactions with nitric acid. (See under *coloring matters of the bile*.) The use of the bile, in digestion, is not yet clearly understood by physiologists.

Uses of Bile. Bile is employed for several technical purposes, such as the removal of stains from clothes, and as an admixture to several paints. It is also employed in medicine. In order to preserve it for these purposes, it is generally evaporated to an extract, in which state it keeps for a longer time, especially if it be previously freed from its mucus by precipitation with alcohol.

BILIARY CONCRETIONS. *Ger.* Gallensteine. Insoluble substances often precipitate from the bile, and form solid masses or concretions. These are called biliary calculi, or gall-stones, and are most frequently found in the gall-bladder, but also in the liver or its ducts. Sometimes they pass into the intestines, and are then evacuated with the feces. They occur both in man and animals.

Biliary concretions consist mainly of cholesterolin and coloring matter, mixed in various proportions. They generally contain also more or less biliary mucus and inspissated bile. According to their various content of coloring matter and its different tints, their color varies from white to yellow, brown, and dark green. Sometimes they are soft and plastic, but more frequently brittle, and pulverizable to an unctuous powder. Their shape is mostly round or oval, but if several occur together in the gall-bladder, they receive from pressure on each other a polyhedral form. Their size varies from very small to that of a walnut.

Biliary calculi in man consist most frequently of cholesterolin, when they are internally white and crystalline. On being dissolved in boiling alcohol, they frequently leave a nucleus of coagulated mucus and coloring matter. They are generally lighter than water. Gren found the specific gravity of a specimen of this variety to be 0.803. When they at the same time contain a large quantity of coloring matter their specific gravity increases, according to

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Thomson, to 1.06, and they become of a dark and brownish color.

The following table exhibits the results of some analyses of gall-stones

	Glaube.	Brandes.	
Dry bile.....	8	3.12	5.66
Cholesterin	56	81.25	63.76
Coloring matter of bile	15	9.38	11.38
Coagulated albumen..	9		
Biliary mucus.....	12	6.25	13.20

Chevalier analyzed a gall-stone, consisting of cholesterolin 96, coloring matter 3. Another, analyzed by John, contained: cholesterolin 93, animal matter soluble in water and alcohol 1, brown coloring matter with mucus 6; another, by Joyenz, cholesterolin 4, green colored bile-resin 5, bile-sugar 6, concrete bile 8, yellow coloring matter 70, phosphate of lime and magnesia 3, oxide of iron and loss 4. Sometimes the cholesterolin and the coloring matter contain quite considerable quantities of phosphate and carbonate of lime, but this is not often the case in human calculi. Bally and Henry, jr. found in a human gall-stone 72.70 pts. carbonate of lime, with traces of carbonate of magnesia, 13.51 phosphate of lime, 10.81 mucus or albumen, besides some oxide of iron and coloring matter. Biliary concretions of *animals* exhibit a much greater variety in their chemical composition. Those of *oxen* consist most frequently of coloring matter. One was found to consist mainly of margaric and margaric acid, with a small portion of coloring matter (*J. Vogel*). One obtained from a *dog* consisted of carbonate of lime, with some phosphate of lime, coloring matter, and a trace of fat. Lassaigne analyzed biliary calculi from *hogs*. They were of an orange yellow color, very light and soft, and lost by drying more than half of their weight. They contained: cholesterolin 6, colorless bile-resin 45, bile 4, animal and coloring matter, phosphate of lime and oxide of iron 45.

A rarer variety of biliary calculi seems to consist mainly of carbon, which, after extraction with water, alcohol, ether, acids, and alkalis, remains as a dark residue without taste, suffering no change by heating in a retort, and burning without flame in oxygen gas, and with the formation of carbonic acid.

Closely allied to biliary concretions is a kind of bezoar, consisting chiefly of a peculiar substance called *Lithofellinic acid*, but it is most probably a concretion formed in the intestinal canal, even should the bile by its passage through this afford the main material for its formation. (See *BEZOAR* and *LITHOFELLINIC ACID*.)

Analysis of Biliary Concretions. No definite rules can be given for the examination of biliary calculi, as they may contain a number of different substances. In general, they may first be pulverized, and then treated with water, which dissolves inspissated bile. The residue may then be treated with ether, which dissolves cholesterolin and fat, which are separated by solution in boiling alcohol and crystallization of the cholesterolin, after which, fat and fatty acids remain in the solution, mixed sometimes with traces of bile-resin. The residue, from the treatment with ether, is then first extracted

with cold alcohol of 0.86, in which solution several of the ingredients of the bile may be sought for, such as cholinic and fellinic acids, and then with boiling anhydrous alcohol, with carbonate of ammonia, and finally with caustic potassa, which dissolves biliary mucus. The latter may be precipitated by acetic acid added in excess, in order to retain in solution a possible content of albumen or other protein compound.

BILIC ACID, BILIFELLINIC ACID, BILIN, BILIVERDIN, &c., &c. See under **BILE**.

BINARY THEORY. *Chem.* See **SALTS**.

BIOTINE. *Min.* See **ANORTHITE**.

BIRCH. The bark and other portions of several species of birch (*Betula*) contain essential oil, *betulin*, &c. Grassmann's analysis of the young leaves of *Betula alba* yielded

Water	54.5
Essential oil with wax	0.3
Aqueous extract, with a yellow bitter, free acid, gum, and albumen	11.4
Alcoholic extract, with resin, chlorophyll, wax, and vegetable fibre	33.8
	100.0

The aqueous extract dissolved in water with a reddish brown color, and contained a yellow bitter substance soluble, and another brown substance insoluble in alcohol. The alcoholic extract made after extracting the leaves with water, contained a solid fat, the greater part of which separates from the cooling alcohol; and the clear solution then evaporated gives a rich green silky extract, soluble in ether with the same color, leaving a brown resin. The essential oil is limpid, colorless, becoming yellow in the course of time, has the peculiar balsamic odor of the fresh leaf, a mild and sweetish taste at first, subsequently burning and aromatic; congeals at 14° without crystallizing. (*Grassmann*.)

Birch-bark (from *Betula alba*) when subjected to dry distillation or burned with imperfect access of air (as in the preparation of lamp-black) yields a tar, very rich in empyreumatic oils, and containing some of the peculiar principles of the plant undecomposed. The tar subjected to distillation yields a brown oily acid liquid, of a strong odor, and lighter than water, which redistilled at different temperatures gives different products; among others, at 212° an oil analogous to oil of terpentine.

Essential oil. The crude oil repeatedly washed with a solution of potassa is distilled at 212°; the yellow oil, treated several times with lime-water, is distilled alone then in an atmosphere of carbonic acid, and the first portions of the last distillation are received separately as the pure oil.

It is colorless, in odor between terpentine and birch-bark; spec. grav. at 68° = 0.847; boils at 313°, density of vapor = 5318; soluble in alcohol and ether, slightly in water, dissolves resins; cooled to 1° to 3° it deposits a white substance. It absorbs oxygen from the air, becoming yellow, thicker and changing by time into a resinous substance.

Formula, $C_{20}H_{16}$.

Boiled with dilute nitric acid, it is changed into a reddish substance soluble, and a yellow substance insoluble in cold alcohol, both of which, like the resins, combine with bases. A small quantity of prussic acid is generated at the same time. (*Sobrero*.)

Betulin or Betulin resin. Discovered by Lowitz in the epidermis of birch-bark, prepared by exhausting the bark with boiling water, extracting the residue with alcohol and evaporating; it deposits in warty masses, which may be purified from solution in ether. Betulin is colorless, insoluble in water, soluble in 120 pts. cold, in 80 pts. boiling alcohol, soluble in ether, fixed and essential oils; fuses at 392° to a colorless transparent liquid, and may be sublimed in a stream of air. Formula, $C_{40}H_{33}O_3$. (*Hess*.)

Essential oil of Betula lenta. (Syn. Sweet, black, cherry-birch growing abundantly in the middle and northern parts of the United States.) The bark of trunk and larger branches coarsely bruised, macerated for several days with water and distilled, yields an oil identical in its properties and behavior to reagents with the oil of *Gaultheria procumbens*. When gently heated with sulphuric acid, it is decomposed, and by standing, the solution becomes a mass of crystals, having all the properties, when purified, of salicylic acid. The oil of vitriol probably acts on the methylic ether, and sets the salicylic acid free. The oil does not appear to exist in the dry bark, for the latter only develops its characteristic odor by contact with water; but by treating the dry bark in a manner analogous to the preparation of amygdalin, a transparent, gummy substance (*gaultherin*) is obtained, which bears the same relation to the essential oil of birch that amygdalin bears to the oil of bitter almonds. The bark appears likewise to contain an albuminous principle, analogous to emulsin, by the reaction of which with gaultherin the oil is generated. (*Proctor*.) See **GAULTHERIA**.

BIRDLIME. Syn. *Ger.* Vogelheim, *Viscum album*, *Fr.* Glu. Prepared by boiling the middle bark of the holly several hours with water, and placing it under ground in a moist situation until it becomes viscous by fermentation; it is next bruised, washed, and kneaded to remove extraneous matter; and lastly left for some days to ferment in earthen vessels. It may likewise be procured from the mistletoe, and other plants. The peculiar substance in it is viscin.

Viscin. The mistletoe contains this peculiar tough and viscous substance in all its parts. It is obtained by repeatedly treating the dried berries with ether; it extracts at first green wax (chlorophyll?) and viscin, and by each successive treatment a purer viscin, which remains colorless after distilling the ether. Viscin is white, opaque, tough, very adhesive, and may be viewed as a kind of soft, undrying resin, similar to a melted mixture of fat and rosin. It is soluble in ether and nitrous ether, but not in acetic ether, which extracts only wax and chlorophyll; soluble in oil of terpentine, rosemary and naphtha, scarcely, if at all in alcohol; soluble in potassa by heat; dilute acids do not act on it; nitric acid changes it into oxalic acid and a solid fat.

Macaire observed that pure viscin is excreted from the flower-base and involucre of the Distaff-thistle (*Atractylis* or *Acarna gum-mifera*). It consists, according to Macaire-Prinsep, of carbon 75.6, hydrogen 9.2, and oxygen 15.2. He holds common birdlime to be a mixture of viscin, bassorin, and acetic acid, and that it is not contained ready formed in the holly or mistletoe, but changed into it by fermentation.

Nees v. Esenbeck and Clamor Marquart state that the milky juice of the green twigs of *Ficus elasticus* contain viscin, instead of caoutchouc, while the latter was contained in the juice of the older branches. With constant clamminess, the toughness of viscin is so great, that when small birds alight on branches smeared with it, they cannot escape; hence the name birdlime.

BISMUTH. *Min.* Syn. Octahedral B. *Mohs.* Native B. *Ger.* Gediegen Wismuth.

Descrip. Cryst. System, Regular Octahedron, with perfect octahedral cleavage. Frequently in imitative crystalline forms; foliated and granular.

H. = 2—2.5 G. = 9.737.

Color reddish white; lustre metallic, brilliant when fresh, subject to a dull tarnish; sectile; very brittle when cold.

Behavior. To distinguish it from metallic tellurium and antimony, with which it may be confounded, Berzelius gives the following. 1. In a closed tube, at the softening heat of glass, tellurium only gives off a little oxidized vapor followed by a gray sublimate of metallic tellurium. 2. In an open tube antimony gives white fumes, covering the glass with a white coating which may be wholly driven by heat from one part to another, while only a small quantity of fused oxide surrounds the bead. Tellurium evolves copious fumes, covers the glass, but fuses into drops when heated, while the metallic bead is surrounded by clear, fused and almost colorless oxide, which on cooling forms a white, lamellar and opaque layer. Bismuth fumes slightly, unless mingled with sulphur, and the bead is surrounded with the fused oxide of a dark brown color while hot, pale yellowish on cooling: it attacks the glass powerfully. 3. On charcoal all three metals fuse, forming a ring on the charcoal, which with antimony is pure white, and with bismuth and tellurium has a red or dark yellow border. When this coating is acted on by the reducing flame, tellurium communicates a rich green color to the flame, antimony a faint greenish blue, and bismuth gives no color. Bismuth fuses at 476°, crystallizing readily on cooling. Soluble in nitric acid, its solution becoming milky by addition of water, and brownish by sulphuretted hydrogen. Native bismuth contains occasionally a little arsenic.

Local. Occurs in gneiss and clay-slate with ores of silver, cobalt, lead and zinc. Its principal localities are in Saxony and Bohemia at Schneeberg, Annaberg, Altenberg, Johanngeorgenstadt, Joachimsthal, &c.; Bieber near Hanau; Transylvania; Carinthia; Modum in Norway; Fahlun in Sweden; Huel Sparnon, Carrook Fell, England. In the United States,

the only known locality is Lane's mine in Monroe, Conn., imbedded in quartz and with tunstate of lime and iron, Galena, blende, &c.

BISMUTH. Syn. Tin-glass, Marcasita. *Ger.* Wismuth, Aschblei. *Fr.* Etain de Glace. Mentioned by Agricola in 1529 as a peculiar metal, more particularly examined by Pott and Geoffroy in 1753, and its compounds more fully by Berzelius, Lagerhielm, J. Davy, and Jacquelin. It may be regarded as rather a rare metal, although the quantity extracted is about sufficient to meet the demand. It is almost exclusively employed in the metallic state to add to lead, to harden it, and render it more fusible, &c., as in stereotype-metal.

METALLURGIC TREATMENT OF BISMUTH.

Of the ores of bismuth, the native metal is most abundant, associated with cobalt and silver ores, and might therefore be regarded as a secondary product in the metallurgic treatment of those ores. (See BISMUTH ORES.) It is principally procured in the Saxon Erzgebirg at Schneeberg, where it is mingled with ARSENICAL COBALT, averaging about 7 lb. to the cwt. From its existence chiefly in the metallic state, and its ready fusibility, it is obtained by Eliquation, with an arrangement analogous in principle to those employed in the eliquation of crude antimony; the ready oxidability of bismuth requiring some precautions to avoid loss.

Pl. IV. figs. 6, 7, and 8 represent the bismuth eliquation furnace of Schneeberg; fig. 6 is a view from above; fig. 7 a vertical section in the line A B of fig. 6; fig. 8 is a view in front along g g of fig. 6. *a* is the ashpit, *b* the fire-place, *c* the eliquation tubes, *d* the fire-hearth or grate of brick-work, supplied with fuel through *e*, fig. 6. The pipes are placed in an inclined position, their lower opening being closed by a clay plate, *f*, with a small circular opening on the lower part through which the fused metal flows into the iron pans *i*, containing a little coal-dust; these rest upon a wall, *g*, with as many fire-flues, *h*, as there are pipes; *l* are the upper back ends of the pipes, closed by a sheet-iron plate; *k* is a wooden water-trough in which the residue (Wismuthgrau-pen) is quenched, falling first on the oblique surface *m*. *n, n* are draft-holes between every pair of pipes designed to increase or diminish the heat at pleasure.

The ore is sorted from the gangue by hand, prepared in pieces of a hazelnut size and smaller, thrown into the red-hot pipes to the amount of about $\frac{1}{2}$ cwt., so that they are filled to $\frac{1}{2}$ their diameter and $\frac{3}{4}$ their length, and tightly closed by the sheet-iron plate. In 10 minutes the metal begins to flow out into the hot iron pans, where oxidation is prevented by the coal-dust. When the eliquation slackens, the charge in the pipes is raked, which is performed several times in the course of a $\frac{1}{2}$ hour, when the operation is complete. The residue (Wismuthgrau-pen) is raked out from the upper end of the pipes into the water-trough, and the pipes re-charged. When the iron pans are nearly full the metal is ladled out into an iron mould, in which it cools in bars of 25—50 lb. weight. A ton of ore is worked off in 8 hours, consuming some 50 cubic feet of wood. The

yield of bismuth at Schneeberg in 1830 was 10,000 pounds.

The bismuth thus prepared, although closely resembling the pure metal, contains variable quantities of arsenic, sulphur, iron, &c.; the presence of the two former may sometimes be recognised by the cracking of the metal on cooling, but unless present in some quantity, they do not materially injure it for technical purposes. For pearl-powder, &c., arseniferous bismuth should be rejected. (See the properties of the metal below.)

I. BISMUTH AND ITS NON-SALINE COMPOUNDS.

Bismuth. *Sym.* Bi. *Equiv.* 213 (or 2660·7 O = 100). The oxide of bismuth, formerly assumed to be Bi_2O_3 , was subsequently changed to BiO , which diminished the equiv. of the metal from 106·5 to 71. According to the formula for the strong base, the equivalent varies;

for BiO	the eq. of Bi	= 71.
" Bi_2O_3	" "	= 106·5.
" BiO_3	" "	= 213.

The analogy between some of the salts of bismuth and those of magnesia and oxide of copper led to the adoption of BiO , but the analogy is not strong, while there is a more striking resemblance between some of the corresponding compounds of bismuth and antimony, and the observation of Kopp strengthens the adoption of Bi_2O_3 , or BiO_3 , viz., that the spec. volume of bismuth expands in the same manner as tin and zinc, when we assume this formula, instead of BiO . We shall therefore employ the formula for the oxide BiO_3 and the eq. of Bi = 213. Gmelin thinks that it should be 210 instead of 213 (or 70 instead of 71, when oxide of bismuth = BiO).

Commercial bismuth may be best purified by solution in nitric acid, evaporating the clear solution, adding water largely to precipitate subnitrate; digesting this with caustic potassa to extract arsenious acid, and reducing the remaining oxide with black flux at a low ignition.

It crystallizes perfectly in octahedrons and cubes, with very distinct cleavage, parallel to the 8-hedral planes. To obtain it well crystallized, fuse the commercial metal in a crucible, add a little saltpeter from time to time, with stirring, and maintain it at the temperature of fusing saltpeter, until a test taken out ceases to exhibit a violet or rose color, which disappears on cooling, but shows a green and yellow color, which it retains on cooling. Pour the metal into a heated crucible, covered with sheet-iron, containing live coals to prevent the surface from congealing, cool it rapidly, and when about $\frac{1}{2}$ is congealed, bore a hole through the solid layer by an ignited coal, and pour out the still liquid metal.

Pure bismuth has a spec. grav. = 9·654, Karsten, 9·799, Marchand and Scheerer; the commercial = 9·783 — 9·833. A cylinder of the commercial metal of spec. grav. 9·783 passed into a steel mortar, and at a pressure of 100,000 lb. has a spec. grav. = 9·779, with 150,000 lb. = 9·655; with 200,000 lb. = 9·556, becoming very brittle and exhibiting a fine-grained, scarcely crystalline structure. A rod of it: $\frac{1}{10}$ inch diameter bears 40 lb. B. is rather soft, has

little ring, is brittle, but may be extended slightly by careful hammering, is more malleable when heated. It is reddish white, with little lustre, fuses at 497° — 508° , and expands on congealing about $\frac{1}{32}$.

At a higher temperature it may be distilled in close vessels, condensing in laminae. It is soluble in nitric and nitro-muriatic acids. It exhibits a similar passive state with iron, though in a less degree by contact with an electro-negative metal; for though rapidly soluble in nitric acid of spec. grav. 1·4, if a piece of platinum be laid upon it in the acid, the action ceases, and each time that contact with the platinum is broken, the bismuth assumes a black coating, which disappears; the metal remains bright and the acid acts feebly or not at all upon it. It is also rendered inactive by dipping it in nitrous and immediately in nitric acids.

1. *Suboxide of Bismuth.* When bismuth is melted in the air at a low temperature, or exposed in fine powder to the air, it becomes coated with a suboxide of a reddish brown color; when basic nitrate of B. is digested with an excess of protochloride of tin, washed with boiling water, and dried in a vacuum, it is also formed of a coal-black color, and burns like tinder to oxide. Its action before the blowpipe with mic. salt resembling that of suboxide of copper, it would seem to be capable of forming salts, at least in the dry way.

2. *Oxide of B.* Ger. Wismuthoxyd. It occurs native as BISMUTH OCHRE. *Formation.* 1. B. does not oxidize in moist air, but when partially covered with water, it first forms hydrated oxide, then fine crystals of oxide, and if the air contained carbonic acid, a hydrous carbonated oxide in white scales is formed. 2. B. heated to a white heat in the air, burns with pale blue flame to oxide or *Flowers of B.* 3. By keeping it fused in the air, removing the dross or *B.-ash* from the surface, until the whole is thus converted, and exposing it to a continued moderate heat. 4. By decomposing steam at a white heat. 5. By the action of nitric acid in the cold, sulphuric with heat, evolving nitric oxide, or sulphurous acid, and forming a salt of B. Fuming nitric acid produces ignition with the powdered metal.

Prep. 1. By removing the dross of the melted metal and exposing it to the continued action of heat. 2. By gently heating basic nitrate or the carbonate of B. 3. By fusing caustic potassa with an excess of oxide of bismuth, or boiling the hydrated oxide with a caustic lye of potassa or soda, it is crystallized. 4. The hydrate is obtained by precipitating the nitrate by caustic potassa.

Prop. Prepared by 1 and 2 it is a pale lemon-yellow powder; by 3. shining, yellow needles; by 4. the hydrate is a white powder. It becomes, temporarily, reddish brown by heat, then fuses to a dark-brown, or black opaque glass, becoming yellow and crystalline on cooling. Fused in a clay crucible, it takes up silica, alumina, &c., forming a yellow transparent glass when cold. Spec. grav. 8·174—8·968. Easily reduced to metal by carbon, potassium, sodium, and carbonic oxide; to sulphuret by sulphur.

BISMUTH.

	H = 1.	In 100 pts.	O = 100.	
Bi... 213	89.87	2660.7	100	
O ₃ ... 24	10.13	300	11.275	
BiO ₃	237	100	2960.7	111.275

3. *Bismuthic acids, &c.* It is probable from the experiments of Stromeyer, Jacquelin, Fremy, and Arppe, that there are several other oxides, and an acid of bismuth.

1. A brown colored oxide is prepared by fusing together oxide of bismuth and caustic soda, boiling the mass with an excess of sodalyle, washing the brown powder with nitric acid, and then with water. (*Fremy.*) Probably the same oxide is obtained by dropping nitrate of bismuth into a boiling solution of chlorited alkali, with an excess of chlorous acid, and boiling the oxide in a solution of caustic potassa to remove the remaining chlorine. Form. BiO₄. (?) (*Arppe.*)

2. When the preceding brown oxide is thrown into fused caustic potassa, or the nitrate is dropped into a concentrated solution of chlorited alkali, a yellow hydrated oxide is produced. Form. BiO₅ + HO. If the chlorited solution be dilute, the yellow tint is different, and the formula is Bi₅O₂₄ + HO. (*Arppe.*) It is evident that these contain the same oxide, which is probably BiO₅, and consists of Bi 84.19 + O 15.81 = 100, although his analyses vary between 83 and 88 per cent. of bismuth. Arppe obtained also a brown oxide, by passing chlorine through caustic potassa in which carbonate of bismuth was suspended, which had the formula BiO₅, and was different in its behavior from the brown oxide above (1).

3. When the yellow oxide (2) is treated with nitric acid, there remains a reddish brown mass which changed so rapidly that it could not be examined, and by the continued action of the acid it passed into green or yellowish brown. The latter had the formula Bi₂O₁₁ + HO. (*Arppe.*) It may be, perhaps, when pure, BiO₆, or what is more probable, may contain an acid BiO₇. These oxides or acids cannot be regarded as ultimately determined.

Sulphurets of Bismuth. 1. *Bisulphuret.* Fuse equal parts of tersulphuret and metallic bismuth, and when beginning to congeal, pour out the still fluid metal. The sulphuret crystallizes in the interior in long, thin, quadratic prisms, with replaced edges (2d prism), very brilliant, metallic, light gray, more fusible than tersulphuret; specific gravity 7.29. Formula, BiS₂. (*Wertheim.*)

2. *Tersulphuret.* BiS₃. Occurs native as BISMUTH GLANCE. Formed readily by fusing bismuth and sulphur together, when it resembles bismuth glance; or by precipitating a salt of bismuth by sulphuretted hydrogen, when it falls in brownish black flocculæ. When fused, it expands considerably on cooling, and after each fusion presses out globules of the metal when congealing. (*Marx.*)

Phosphuret. Phosphorus has little affinity for bismuth, a small quantity combining with it in the dry way, and rendering it more brittle and less foliated. Phosphuretted hydrogen precipitates from nitrate of bismuth a black phosphuret, which loses all its phosphorus by distillation.

BISMUTH.

		Bucholz and Klaproth.	J. Davy and Thomson.	Proust.
Lagerhielm.	Gmelin.			
89.863	89.67	89.28	90	88
10.137	10.33	10.72	10	12
100	100	100	100	100

Alloys. Bismuth combines readily with the metals, forming compounds, which are generally brittle and very fusible. It readily unites with potassium and sodium, and the alloy may also be obtained by fusing bismuth with bitartrate of potassa. The sodium alloy expands considerably during congelation. These alloys are oxidized by water, hydrogen being given off and pure pulverulent bismuth being left. B. combines with arsenic with the same difficulty as with phosphorus; with antimony it may be fused in every proportion, and when the alloy contains 33 or more per cent. of bismuth it expands on cooling. B. forms with tungsten a submetallic, brittle mass of a brownish color; with copper a pale red and brittle compound. It is chiefly employed in an alloy with lead, to impart greater fusibility and a little expansion in congelation. See LEAD, TYPE METAL, SOLDER, AMALGAM.

SALTS.

The salts of B. are easily obtained by solution of the oxide in liquid acids, by the decomposition of a portion of the acid; or some of the insoluble by double decomposition. They are colorless with a colorless acid, have a high spec. grav., are poisonous; the soluble decomposed by water into a basic and acid salt, or a basic salt and free acid, unless they are in a very acid solution. The carbonated alkalies precipitate the carbonate, carbonated alkaline earths the hydrated oxide; sulphuretted hydrogen and sulphhydrates precipitate all the bismuth present as a brownish black sulphuret, insoluble in excess of precipitant, even from a very acid solution. Iodide of potassium gives a brown iodide, soluble in an excess of precipitant. Alkaline chromates throw down yellow chromate. Yellow prussiate of potassa produces a white precipitate insoluble in muriatic acid; red prussiate a pale yellow, soluble in muriatic acid. B. is precipitated metallic by zinc, cadmium, tin, iron, lead, copper; by the two first rapidly; by the three following more slowly, by the last, copper, it is wholly thrown down, only when the solution is warm.

Analysis. Ullgren separates lead and bismuth by precipitating them with carbonate of ammonia, dissolving in acetic acid, and putting in a clean and weighed piece of metallic lead in a closed vessel for a few hours. Collect the bismuth on a filter, wash with boiled and cooled water, dissolve in nitric acid, evaporate to dryness, ignite, and weigh as oxide of bismuth. The lead solution is precipitated by carbonate of ammonia, the oxide of lead weighed, and the amount deducted from it, which it gained from the strip of metallic lead.

Haloid Salts.

1. *Chloride of Bismuth.* Syn. Butter of B. Ger. Chlorwismuth. Prep. B. takes fire in

chlorine and forms *chloride of bismuth*. 2. It is obtained by heating 1 pt. bismuth with 2 pts. corrosive sublimate. 3. Dissolve B. in strong chlorohydric acid and evaporate to crystallize.

Prop. Brownish or grayish white, opaque, and of a granular texture, or from the 3d process it crystallizes in prisms. It fuses readily to an oily liquid, volatilizes by a gentle heat; decomposes by water into free muriatic acid and oxychloride (2). Form. BiCl_3 ; eq. 313.5; in 100 pts. Bi 66.73 + Cl 33.27.

2. *Oxychloride of B.* Syn. Basic chloride of B. *Prep.* Decompose 1 with water and wash the residue. 2. Pass steam over fused chloride of B. 3. Precipitate a solution of B. in nitric acid by a strong solution of common salt, chloride of potassium (not in excess), or by moderately dilute muriatic acid.

Prop. Crystalline, white, becoming yellow at every ignition, fuses without decomposition. Decomposed by hot sulphuric acid into sulphate, by heating in chlorine into chloride, by concentrated potassa into oxide of bismuth. Insoluble in water, soluble in nitric and muriatic acids. Formula, $\text{Bi}_2\text{Cl}_3\text{O}_6$ or $\text{BiCl}_3 + 2\text{BiO}_3$, and contains 80.56 per cent. bismuth.

3. *Double Chlorides* are obtained by dissolving 1 eq. chloride of B. and 2 eqs. of the alkaline chlorides in muriatic acid, and evaporating until the salt begins to form, when, on cooling, it crystallizes. Form. of the potassium salt, $2\text{KCl} + \text{BiCl}_3 + 5\text{HO}$; of the sodium salt, $2\text{NaCl} + \text{BiCl}_3 + 6\text{HO}$. The double salt of ammonia contains no water, and forms double 6-sided pyramids isomorphic with the double salt of terchloride of antimony and sal-ammoniac.

Bromide of B. BiBr_3 . Introduce bismuth in powder, with a great excess of bromine, into a long tube, closed at one extremity, and expose it to heat. Yellow vapors appear and condense on the sides of the tube; that which remains at the bottom of the tube is bromide of bismuth, of a steel-gray colour, having the aspect of fused iodine. It fuses at 392° , assuming a hyacinth red color; but, on cooling, resumes its gray color; exposed to the air, it rapidly absorbs moisture, and assumes a fine sulphur yellow color; more water decomposes

it into hydrobromic acid and oxybromide of bismuth.

1. *Subiodide of B.* By heating about equal parts of bismuth and iodine together, they fuse, and the compound sublimes even before fusion in scales with a metallic lustre. Formula, Bi_2I_3 . (?)

2. *Iodide of B.* Make a solution of B. clear by acetic or muriatic acid, precipitate by water, and add iodide of potassium. Brown, crystalline, somewhat decomposed by washing. Form. BiI_3 .

3. *Iodide of B.* Obtained by boiling subiodide (1) with water. A brown powder, decomposed by concentrated solutions of potassa, soda, and strontia.

Fluoride of B. Precipitates by evaporating its aqueous solution as a white powder.

Oxysalts.

Sulphate of B. $\text{BiO}_3 + 3\text{SO}_3$. Obtained by dissolving the metal in oil of vitriol and evaporating to dryness. Ignited in hydrogen it leaves pure bismuth. It is resolved by water into a soluble acid salt and an insoluble basic salt, with the formula $\text{BiO}_3, \text{SO}_3$.

Sulphite of B. Sulphurous acid forms a salt with hydrated oxide of B., insoluble in water and sulphurous acid, and which loses its acid by heat.

Nitrate of B. a. *Neutral.* Dissolve bismuth in warm nitric acid and set it aside to crystallize. If the metal be powdered, and concentrated fuming acid be poured over it, the heat rises to ignition. It forms 6 and 8-sided prisms, apparently doubly oblique rhombic, terminated by several planes, transparent and colorless; they are soluble in dilute nitric acid; water decomposes them into a basic salt, b, which precipitates, while the neutral salt and free nitric acid remain in solution. (Freundt.) Heated to 212° this salt separates into a solid and fluid portion, the latter of which rapidly congeals on cooling; heated more highly, it loses nitric acid and water, leaving a basic salt, and by a still higher heat the oxide alone remains. It deflagrates slightly on ignited coals, more violently by friction with phosphorus.

	H=1.	In 100 pts.	Berzelius.	Duflos.	Freundt.
BiO_3	237	49.38	48.8	48.3	49.00
3 NO_5	162	33.75	33.7	33.5	33.25
9 HO	81	16.87	17.5	18.2	17.75
	480	100	100	100	100

Form. $\text{BiO}_3, 3\text{NO}_5 + 9\text{HO}$. The analyses of Duflos and Freundt indicate 10 eq. water. It is employed for preparing the basic salt.

b. *Basic.* Syn. Magistery of B., Pearl-white, Pearl Powder; Ger. Perlweiss, Schminkweiss; Fr. Blanc d'Espagne. Prepared by adding water to the neutral salt (see a). The greatest yield is obtained by adding 2400 pts. of boiling water to 100 pts. of the crystals, a, which gives 45.5 of the basic salt; and washing with not too great an excess of water. By evaporating this acid solution without the wash-water, nitric acid passes off, and the neutral salt crystallizes, which may again be decomposed by water,

leaving still a portion of neutral salt in solution. To obtain nearly all the bismuth salt, the last solution may be added to the acid water of the first decomposition. (Duflos and Freundt.) Bismuth usually contains arsenic, to avoid which Duflos dissolves 100 pts. of the crystals, a, in 200—300 warm water, which leaves arseniate of B., and pours the clear liquid into 2400 pts. water. Wittstein removes arsenic by boiling the nitrate with caustic potassa, which extracts the nitric and arsenious acids, leaving oxide of B.; the oxide is again dissolved in nitric acid.

Prep. As above prepared, it is a pure white,

BISMUTH.

somewhat pearly, loose powder, possessing great body; composed of crystalline scales when seen under the microscope. Prepared from the acid solution, or with little water, it consists of less minute needles and scales, with a more silky lustre. It reddens moistened

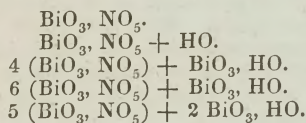
BISMUTH BLENDE.

litmus paper, is insoluble or nearly so in water, becomes more basic by washing, especially with hot water.

The exact composition of the basic nitrate is not known, unless we admit the existence of several distinct compounds.

	H = 1.	In 100 pts.	Phillips.	Gmelin.	Herberger.	Duflos.	Grouvelle.	Freundt, a.	b.
BiO_3	237	81.44	81.92	80.67	79.70	80.00	81.37	80.00	80.60
NiO_5	54	18.56	18.36	16.41	14.44	13.58	13.97	15.39	14.05
HO.....				2.92	5.86	6.42	4.66	4.61	4.45
	291	100	100.28	100	100	100	100	100	100

Phillips' salt was obtained from an acid solution, and Ullgren finds that the acid solution, as well as the acid liquid remaining from the decomposition of the neutral salt by water, yield a salt of similar constitution. Its formula is therefore $\text{BiO}_3, \text{NO}_5$. Gmelin's analysis of the precipitate thoroughly dried, gives nearly $\text{BiO}_3, \text{NO}_5 + \text{HO}$. The analyses of Herberger and Duflos give $5 \text{BiO}_3, 4 \text{NO}_5 + \text{HO}$, which may be $4 (\text{BiO}_3, \text{NO}_5) + \text{BiO}_3, \text{HO}$. Those of Grouvelle and Freundt, *b*, give $7 \text{BiO}_3, 5 \text{NO}_5 + \text{HO}$, or $5 (\text{BiO}_3, \text{NO}_5) + 2 \text{BiO}_3, \text{HO}$, while the other analysis of Freundt, *a*, yields nearly $7 \text{BiO}_3, 6 \text{NO}_5 + \text{HO}$. Admitting the researches to be correct, we have the following basic nitrates:



Use. Subnitrate of B. or pearl powder is employed as a cosmetic from its pure white color, but it should be remembered that it is apt to become gray in color of itself, and to darken by sulphuretted hydrogen. It is farther employed to a limited extent in medicine internally, and as an ointment.

1. *Phosphate of B.* Aqueous phosphoric acid combines with hydrated oxide of B. by digestion, forming partly a white, insoluble powder, which fuses before the blowpipe to a white enamel, and is decomposable by carbon, partly a crystallizable salt, soluble in water.

2. *Pyrophosphate of B.* Syn. Bibasic phosphate of B. Formed by precipitating a salt of B. by pyrophosphate of soda, is soluble in an excess of the precipitant.

3. *Metaphosphate of B.* Syn. Monobasic ph. of B. Add metaphosphoric acid and then ammonia to a solution of nitrate of B. It is insoluble in an excess of ammonia.

Phosphite of B. Terchloride of phosphorus dissolved in water, neutralized by ammonia, and added to a solution of chloride of B. partially neutralized by ammonia, produces a voluminous white precipitate, which evolves pure hydrogen by distillation.

Bromate of B. Bromic acid left for a long time in contact with hydrated oxide of B. forms an insoluble and a soluble salt. The latter acid solution yields by evaporation bromine and oxygen, leaving a little deliquescent salt. The former is a white amorphous powder, loses its water between 302° and 320° , decomposes violently at a higher temperature, leaving yellow

low oxybromide of B. $3 \text{BiO}_3, 2 \text{BrO}_5 + 6 \text{HO}$. Eq. 1001.8.

Iodate of B. Iodic acid and an alkaline iodate give, with nitrate of B., a white precipitate insoluble in water.

Carbonate of B. Formed by dropping nitrate of B. into a solution of carbonate of potassa; a white powder insoluble in carbonated water. It is a basic salt, and has been employed in medicine

Borate of B. A white powder almost insoluble in water.

Silicate of B. An impure silicate, BISMUTH BLENDE, occurs native. Oxide of B. dissolves in glass with a yellowish color.

Sulphocarbonate of B. Formed by adding sulphocarbonate of lime to a solution of B. It is a dark brown powder, soluble in an excess of the precipitant with a bright reddish brown color.

BISMUTH BLENDE. *Min.* Syn. Arsenical Bismuth, Silicate of B. *Ger.* Kieselwismuth. *Descrip.* Cryst. system, Regular, but only in the hemi-forms of the $\frac{3}{2}$ -hedron, $\frac{2}{4}$ -hedron, or these 2 right hemi-forms combined. Cleavage imperfect parallel to 12-hedron; crystals minute. It occurs also in globular masses with columnar, lamellar, or granular structure.

H. = 3.5 — 4.5. G. = 5.912 — 6.0.

Color, dark hair-brown or light yellowish; lustre resinous or adamantine; subtransparent, opaque; streak yellowish gray; rather brittle, with uneven fracture.

Behavior. In a closed tube decrepitates, giving traces of water; on charcoal froths and fuses readily to a brownish bead, giving off fumes (which sometimes have an arsenical odor), and coating the coal yellowish brown; dissolves in mic. salt, giving traces of iron, and leaving a skeleton of silica; with soda gives metallic bismuth.

Decomposed by acids with the separation of gelatinous silica; muriatic is the best solvent. Heated in a platinum crucible with sulphuric acid it exhibits traces of fluohydric acid.

Average of two analyses by Kersten:

Silica	22.23
Oxide of bismuth.....	69.38
Phosphoric acid.....	3.31
Peroxide of iron	2.40
Peroxide of manganese.....	0.30
Water and fluohydric acid....	1.01
Fluohydric acid and loss	1.37

100

333

BISMUTH COBALT.

Omitting the iron as unessential, its formula is 5 (3 BiO, 2 SiO₂) + 4 BiO, PO₅, mingled with a little silicofluoride of bismuth.

Locality. It accompanies cobalt ores and native bismuth near Schneeberg in Saxony.

BISMUTH COBALT. *Min.* Kersten analyzed a mineral from Schneeberg to which he gave this name, but it appears to be an aggregate, containing a large proportion of arsenical cobalt and Bismuth glance.

BISMUTH GLANCE. *Min. Syn.* Prismatic B. G. Mohs. Sulphuret of B.; Bismuthine. *Ger.* Wismuthglanz. *Descrip.* Cryst. system, Right Rhombic, crystals acicular, presenting several vertical prisms, and terminal planes of the three axes, with two first and one second horizontal prisms. Cleavage parallel to all the terminal planes, most perfect to the terminal plane of first lateral axis. Occurs also massive with foliated or fibrous structure.

H. = 2 — 2.5. G. = 6.549.

Color and streak lead-gray; lustre metallic; opaque; sectile.

Behavior. In an open tube sublimes sulphur, gives off sulphurous acid, and boils; on charcoal in reducing flame fuses readily with spitting to a bead of metallic bismuth, and forms a heavy yellow coating. Soluble in nitric acid, with the separation of sulphur; water renders the solution turbid.

Analysis. 1. From Riddarhyttan in Westmanland by Rose; 2. from Retzbanya by Wehrle; 3. from Cornwall by Warrington.

	1.	2.	3.
Bismuth.....	80.98	80.96	72.49
Sulphur.....	18.72	18.28	20.00
Iron.....	—	—	3.70
Copper.....	—	—	3.81
	99.70	99.24	100

By abstracting copper pyrites from 3, it leaves the same compound as 1 and 2. Its formula is therefore BiS, a simple sulphuret of bismuth. Berzelius infers the existence of a lower sulphuret from the behavior of a bismuth glance from Gregersklack, as it did not sublime sulphur.

Local. Occurs generally in same localities as native bismuth; associated with cerium-ore at Bastnaes, in Sweden. In the United States, it is said to have been found at Haddam, Connecticut.

BISMUTH OCHRE. *Min. Syn.* Oxide of B. *Ger.* Wismuthocker. It occurs massive and disseminated; pulverulent, earthy, sometimes lamellar. G. = 4.361. Color yellow, grayish white; lustre adamantine, dull; opaque. Behaves like pure oxide of bismuth, often containing iron, copper, arsenic, carbonic acid, and water. It occurs on the ores of bismuth and its associates at Schneeberg, Saxony; Joachimsthal, Bohemia; Beresof, Siberia.

BISMUTH ORES. *Min.* The following are the principal minerals in which bismuth is found:

BITTER PRINCIPLE.

Min. name.	Formula.
Bismuth.....	Bi
Bismuth ochre..	BiO
Bismutite	BiO, CO ₂ (?)
Bismuth blende..	(a silicate)
Bismuth glance..	BiS
Telluric bismuth	BiS + 2 BiTe.
Bismuth silver..	m (Pb, Bi, Ag) S (?)
Copper bismuth.	Cu ₂ S, BiS
Needle-ore.....	Cu ₂ S, BiS + 2 (PbS, BiS)

BISMUTH SILVER. *Min. Ger.* Wismuthsilbererz. Generally amorphous, rarely acicular. Color tin-white, tarnishing; lustre metallic; soft and sectile.

Analysis by Klaproth of B. S. from Schapbachthal in Schwarzwalde, but from the method pursued the analysis cannot be relied on. (*Ram.*)

Lead	33.0
Bismuth.....	27.0
Silver	15.0
Iron	4.3
Copper	0.9
Sulphur.....	16.3
	96.5

BISMUTHINE. *Min.* See BISMUTH GLANCE.

BISMUTITE. *Min.* Disseminated acicular crystals. H. = 4 — 4.5, or 3.5 when they have lost their lustre. G. = 6.86 — 6.91. Color mountain-green, occasionally straw-yellow and yellowish gray; lustre vitreous, dull; subtranslucent, opaque; streak greenish gray to colorless; brittle.

Behavior, &c. Fuses on an ignited coal, being reduced with effervescence to a globule of metallic bismuth, and producing a coating of the oxide. Forms a deep yellow solution with chlorohydric acid. According to Plattner's tests, it is carbonate of bismuth with (probably carbonates of) iron and copper, and sulphuric acid.

Local. It occurs in Cornwall, at Schneeberg, Saxony, and near Hirschberg in Russian Voigtland, with other ores of bismuth. (*Dana.*)

BISTRE. A brownish black color, prepared and used similarly to China ink. That portion of wood-soot which collects in the lower portions of a flue or chimney from imperfect combustion, is usually more compact, and consists of carbon more highly charged with empyreumatic products, pyro-resin, ammoniacal and alkaline compounds, &c. The soot arising from beech wood is preferred. It is pulverized, sifted, washed with cold and sometimes warm water to remove the soluble saline ingredients; and washed over to obtain the finest particles. The finest sediment is then mixed with gum-water, moulded into cakes, and dried. It is only used as a water color.

BITTER ALMONDS. See ALMOND and AMYGDALIN.

BITTER PRINCIPLE. *Ger.* Bitterstoff. The extractive portion of many plants is often termed *bitter extract* or *bitter extractive*, from its possessing a bitter taste, and is divided into *mild, acrid, and narcotic*.

Prep. 1. The bitter portions of plants, if

BITTER PRINCIPLE.

fresh, are pressed, or if dry, are extracted with water, and the juice or solution concentrated by evaporation, when a deposit usually takes place, consisting of albumen, apothem, and insoluble salts of lime, &c. The filtered liquor is evaporated to an extract, and treated with dilute alcohol, which extracts the bitter principle in a purer state, leaving starch, gum, salts, &c.

2. Prepare an extract of the plant directly with dilute alcohol and treat it with water, which dissolves the bitter, leaving resin. In either case the solution yields, by evaporation, a dark-colored extract, which, besides the bitter, contains resin, sugar, coloring matter, and various salts. Absolute alcohol removes resin and some salts; some of the salts may also be removed by adding sulphuric acid to the tincture, and forming sulphates insoluble in alcohol, while the excess of sulphuric acid is removed by carbonate of lead. Sugar is removed by fermentation. The coloring matters are removed by neutral acetate of lead. To the filtered solution add basic acetate of lead, wash the precipitate with a little cold water, suspend it in water, decompose it by sulphuretted hydrogen, filter, and evaporate. The bitter principle thus obtained is probably not always free from a little foreign admixture.

Prop. The bitter principle is uncrystallizable, yellowish or brownish, translucent, and, after perfect drying, brittle, with conchoidal fracture, and pulverizable. It is heavier than water, inodorous, with a pure bitter taste, soluble in water and spt. wine, but not in absolute alcohol, ether, or the oils. Subjected to dry distillation it yields gases, an acid, generally an ammoniacal liquid, empyreum. oil, and charcoal. It burns with a feeble flame in the air, leaving a porous charcoal, which generally yields ashes by combustion.

By repeated evaporation, or by the action of chlorine, it deposits *APOTHEM*. Its solution is rendered darker by alkali without precipitation. Alumina, most metallic oxides, and especially basic acetate of lead, form insoluble or difficultly soluble precipitates. It does not precipitate with gelatin. Many bitters are abstracted from a solution by boiling with bone-black, with which they enter into combination. The above properties are general, and subject to exceptions from the presence of other substances.

The exact chemical character of the different kinds of bitter has not been determined, nor is it at all probable that they will agree in their constitution, or other essential characteristics. The following list comprises some of those best determined, which are free from nitrogen, and have a neutral reaction.

Absinthiin, flowers of *Artemisia absinthium*.

Aloin, *Aloë spicata*.

Bryonin, root of *Bryonia alba*.

Cathartin, leaves of *Cassia lanceolata*.

BITTER SPAR.

Cetrarin, *Cetraria Islandica*.

Colocynthin, seed-pulp of *Cucumis Colocynthis*.

Columbin, root of *Menispermum palmatum*.

Cusparin, bark of *Galipea cusparia*.

Daphnin, *Daphne Mezereum*, &c.

Elaterin, fruit of *Momordica elaterium*.

Ergotin, Ergot of Rye.

Fraxinin, bark of *Fraxinus excelsior*.

Gentianin, root of *Gentiana lutea*.

Hesperidin, spongy part of Orange-rind.

Ilicin, leaves of *Ilex aquifolium*.

Lactucin, *Lactuca sativa*, &c.

Liriodendrin, root-bark of *Liriodendron tulipifera*.

Lupulin, female flowers of *Humulus Lupulus*.

Olivil, Gum-resin of *Olea Europea*.

Olivin, leaves of do. do.

Picrolichenin, *Variolaria amara*.

Picrotoxin, *Menispermum cocculus*.

Phyllirin, bark of *Phillyrea media*.

Quassiin, wood of *Quassia amara*.

Scillitin, bulb of *Scilla maritima*.

Tanacetin, *Tanacetum vulgare*.

Tanghinin, seeds of *Tanghina Madagascariensis*.

Xanthopierin, bark of *Xanthoxylon Clava Herculis*.

BITTER SPAR. Syn. Macrotypous Lime-Haloid, *Mohs*; Ankerite; Brown Spar; Conite; Dolomite; Guhrhofian; Magnesian Limestone; Miemite; Pearl Spar; Rhomb-spar.

Descrip. Cryst. system, Hexagonal, closely resembling calcareous spar, and differing only in the angles (see *ATOMIC VOLUME*). It occurs only in hemiedric forms, the radical rhomb R on R = 106° 15', and two more acute rhombs; the latter are rare; it has been found compounded. It also occurs imitative, amorphous, and granular, like marble.

H. = 3·5 — 4. G. = 2·85 — 3·1.

Color white, reddish, brownish, greenish; also brown, green, rose-red, gray, and black; lustre sub-pearly, often vitreous; translucent; brittle.

Behavior. It closely resembles calcareous spar or pure lime; many of the varieties show a content of more or less iron or manganese, especially ankerite, which may become magnetic by calcination. Soluble with considerable effervescence in chlorhydric acid; and in sulphuric yielding crystals of Epsom salt.

Analysis. 1. Guhrhofian; 2. Crystallized B. spar from Hall, Tyrol; and 3. Fibrous from Taberg by Klaproth; 4. Crystalline from Phillips-town, N. J., by Dr. Beck; 5. Miemite, from Kolozoruk near Bilin by Rammelsberg; 6. Fibrous, from Glücksbrunn by Klaproth; 7. Dolomite, from Liebenstein by Wackenroder; 8. do. Spezzia by Laugier; 9. Cryst. colorless from Jena by Luckow; 10. ditto yellow; 11. Dolomite, black, from Scheidam by Göbel; 12. Cryst. from Zillerthal; and 13. fibrous, from Orenburg by Klaproth; 14. Conite, from Meissner, Hessia, by John.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
CaO, CO ₂	70·5	68·0	73	71·58	60·996	60·0	63·875	55·36	55·2	51·7	53·50	52	51	28·1
MgO, CO ₂	29·5	25·5	25	28·42	36·530	36·5	33·237	41·30	44·7	42·0	41·50	45	47	67·4
FeO, CO ₂	—	1·0	—	—	2·742	4·0	0·912	—	—	—	1·50	—	—	3·5
MnO, CO ₂	—	—	—	—	—	—	0·073	—	—	6·1	—	—	—	—
Fe ₂ O ₃	—	—	2·25	—	—	—	—	2·00	—	—	—	3	1	—
	—	4·0	—	—	—	—	1·050	0·50	—	—	2·75	—	—	—
	100	98·5	100·25	100	100·268	100·5	99·147	99·16	99·9	99·9	99·25	100	99	99·9

BITTER SPAR.

BITUMEN.

The following 6 were analyzed by Berthier, and 7 by Schröter. 1, from Villefranche; 2, from Schams; 3, from Mühlen; 4 and 5 from

Vizille; 6, Ankerite from Goldrath in Styria; 7, Ankerite from Hohe Wand in Styria by Schröter.

	1.	2.	3.	4.	5.	6.	7.
CaO, CO ₂	60.9	47.8	50.5	50.0	50.9	51.1	50.113
MgO, CO ₂	30.3	28.9	32.4	30.8	29.0	25.7	11.846
FeO, CO ₂	6.0	13.7	12.3	13.4	18.7	20.0	35.308
MnO, CO ₂	3.0	0.3	—	0.4	0.5	3.0	3.084

In the 1st table the 4. in No. 2 consists of clay and water, the 1.05 in 7 is organic matter, the 0.5 in 8 is silica, and the 2.75 in 11 is a residue. In the 2d table several of the specimens analyzed by Berthier contained foreign matter.

Notwithstanding the variations in the relative proportion of the carbonates, they appear to be combined in a definite ratio in the purest specimens, as may be seen in the following table.

Tabular View of the Formulas of Bitter Spar.

		Numbers.	Table.
I. a.	CaO, CO ₂ + MgO, CO ₂	8—13	1
b.	CaO, CO ₂ + $\left. \begin{matrix} \text{MgO} \\ \text{FeO} \end{matrix} \right\} \text{CO}_2$	1—3	2
c.	4 (CaO, CO ₂) + $\left\{ \begin{matrix} 3 (\text{MgO}, \text{CO}_2) \\ 1 (\text{FeO}, \text{CO}_2) \end{matrix} \right\}$	4	2
d.	3 (CaO, CO ₂) + $\left\{ \begin{matrix} 2 (\text{MgO}, \text{CO}_2) \\ 1 (\text{FeO}, \text{CO}_2) \end{matrix} \right\}$	5	2
e.	5 (CaO, CO ₂) + $\left\{ \begin{matrix} 3 (\text{MgO}, \text{CO}_2) \\ 2 (\text{FeO}, \text{CO}_2) \\ 2 (\text{MnO}, \text{CO}_2) \end{matrix} \right\}$	6	2
f.	8 (CaO, CO ₂) + $\left\{ \begin{matrix} 3 (\text{MgO}, \text{CO}_2) \\ 5 (\text{FeO}, \text{CO}_2) \end{matrix} \right\}$	7	2
II.	3 (CaO, CO ₂) + 2 (MgO, CO ₂)	5—7	1
III.	2 (CaO, CO ₂) + (MgO, CO ₂)	1—4	1
IV.	(CaO, CO ₂) + 3 (MgO, CO ₂)	14	1

There are evidently 4 classes, with several varieties in the 1st class. The general type of the first class is represented by I. a., consisting of one equiv. of each carbonate; the varieties b to f contain the carbonates of iron and manganese, replacing the carbonate of magnesia. Those analyses which approach most nearly to their formulas are in I. a., analysis No. 9; in II. No. 6; in III. No. 1.

It is evident that those of the 2d table approximate to the ferruginous magnesite, under which Rammelsberg has placed them, but their large content of lime ranks them more naturally with bitter spar. In consequence of the large content of iron in ankerite it has been recognised as a distinct species by some mineralogists, but its formula, and the measurement of its angles, requires that it should be included with bitter spar.

Localities, &c. Dolomite (from Dolomieu) is applied to the granular magnesian limestones; when the crystals are distinct, have curved faces and a pearly lustre, they are termed *pearl spar*, when brown from the presence of iron *brown spar*. From the presence of magnesia (bitter earth) it was termed bitter spar. *Guhrhofian* or *Gurhofite* and *Miemite* are named from the localities Guhrhof in Lower Austria, and Miemo in Tuscany. Beside the above foreign localities, it is abundantly disseminated through the United States. Pearl spar occurs at Lockport, Niagara Falls, Rochester, Glen's Falls, New York, at Phoenixville above Philadelphia, Pennsylvania, &c.; crystallized Dolomite at Quarantine, Staten Island, New York, and Ho-

boken, New Jersey; the latter modified by a combination of 2 rhombs; brown spar at Warwick, Orange county, and with the lead-ore, St. Lawrence county, New York, Manayunk, near Philadelphia, Pennsylvania, &c.; Guhrhofian, Phillipstown, New York; Ankerite at Quebec, and at West Springfield, Massachusetts.

Magnesian limestones are abundant in the United States; those around Philadelphia and Baltimore often containing $\frac{1}{3}$ carbonate of magnesia. They are extensively and successfully applied as a manure for the soil; and they usually make a strongly binding mortar or cement. For some chemical manufacturing purposes, it is by no means immaterial how much magnesia they contain, nor can we assume with safety that by using a larger quantity it will be an equivalent in the amount of strong alkaline base. Thus magnesia renders the slag of the blast-furnace more difficult of fusion; with sulphuric acid, it forms a much more soluble salt than sulphate of lime. (Refer to MAGNESITE.)

BITTERN. *Tech.* The mother-water remaining after extracting common salt by evaporating sea-water. It is used to prepare sulphate of magnesia, &c. See under SODIUM, WATER.

BITUMEN. *Tech.* Another name for Asphalt, but the term bitumen may rather be employed generically to denote the compounds of carbon and hydrogen with or without oxygen, existing in asphalt, petroleum, coal, &c., so that the terms bituminous slate, coal, &c. are properly employed, although their constituents are combined in varying proportions. For the

chemical characters refer to ASPHALT, PETROLEUM.

Bituminous substances are *Amber, Asphalt, Berengelite, Coal, Elastic Bitumen, Fossil Copal, Guayaquilite, Hartite, Hatchetine, Idrialin, Isolyte, Middletonite, Ozokerite, Petroleum, Retinasphalt, Rock Tar.*

Use. Asphalt enters into the composition of some black varnishes, and rock-tar boiled to a certain consistency may be employed alone, while hot, especially if some resin be fused with it.

Bituminous Mastic, or Asphalt, has been extensively employed in France, and has received some attention in the United States for covering roofs, pavements, floors, and lining cisterns. A bituminous limestone is ground and added to $\frac{1}{3}$ of its weight of asphaltum, fused in an iron kettle, and when sufficiently homogeneous it is spread over the surface to be covered. A mixture of coarse and fine pebbles, fragments of brick, stone, &c. are often introduced into the mass for pavements. Coal-tar yielding by evaporation a pitch resembling asphalt, but more brittle when cold, may be employed as a substitute for asphalt, mixed with lime, pounded brick, and stones. Such a pavement, tried at the Philadelphia gas-works, bore the wear of carts passing over it for a considerable time without material injury. When asphalt is employed for the floor of a hall, or entrance, to which it is well adapted, it may be ornamented with any device by impressing in its surface while hot small pebbles of the same or different colors.

BITUMINOUS SHALE. *Geol.* Slates impregnated with bitumen, which is sometimes so abundant that they may be employed as fuel. The slates containing iron pyrites are also employed in the manufacture of ALUM. The bituminous impregnation of the copper-slate of Germany allows it to be treated metallurgically for COPPER, notwithstanding its small content of copper-pyrites.

BITUMINOUS COAL. See COAL.

BLACK COPPER. *Tech.* Crude or coarse metal. See COPPER.

BLACK DYE. *Tech.* The basis of black dyes for all organic fabrics is the tannogallate of iron; but the modes of application vary with the nature of the fabric, whether silk, wool, or cotton. The finest blacks are obtained by a combination of colors; thus a rich black is imparted to wool by grounding it with a deep indigo-blue, then passing it through logwood, galls, or sumach, and finally through a bath of these with copperas and verdigris, or immediately through the latter.

BLACK FLUX. *Chem. Tech.* Prepared by igniting cream of tartar in close vessels, converting it into a mixture of carbon and carbonate of potassa. See TARTARIC ACID.

BLACK JACK. *Mining.* Applied to a black blende or sulphuret of ZINC.

BLACK LEAD. See GRAPHITE.

BLACK WAD. *Min.* See WAD.

BLANQUININ. *Chem.* A supposed alkaloid found by Dr. Mills in white Cinchona bark (*C. ovalifolia*), not farther examined.

BLEACHING. *Ger.* Bleichen; *Fr.* Blanchiment. The destruction or removal of color

from an organic substance, the main mass of which is white, is termed bleaching; thus yellow beeswax, by a careful exposure to the atmosphere, will eventually become white, without any other material change in its properties, as the yellow coloring matter does not necessarily belong to it. In this sense, some of the discharges employed in calico-printing are bleaching agents, but we propose confining ourselves in the present article to the methods of removing color from organic fibre, such as cotton, linen, &c., either to prepare it for receiving other colors by dyeing or printing, or to throw it into commerce with a pure white color. The methods formerly pursued, and still practised, consist in exposing cotton, &c. to the action of atmospheric agents or sulphurous acid derived from burning sulphur, assisted by soap and alkali, but within the present century chlorine has become the principal bleaching agent, especially for cotton goods. We may remark in passing, that the use of chlorine for bleaching, a substance which emanated from the laboratory of the theoretic chemist, has been one principal cause of the present extensive production and consumption of cotton goods, even independently of the improvements in machinery which have distinguished the last century.

I. ATMOSPHERIC BLEACHING.

It is only employed for linen and cotton, the latter of which is the simpler and easier.

Cotton.

Cotton contains naturally a little coloring matter, which is easily bleached, but as this operation is performed on the spun or woven goods, the weaver's dressing, grease, and other impurities must be removed at the same time.

The process consists, 1st, in steeping the cotton in water (not too cold), in order to destroy the weaver's dressing by fermentation, which takes place in from 1 to 6 days, according to the weather and the kind of goods, when it is thoroughly cleansed in the dash-wheel, or otherwise.

2d. *Bleaching.* The goods are then spread out on the grass, and exposed for 2 to 6 days to the action of the sun, air, and moisture, sprinkling them occasionally with water, if necessary; and then bucked with a hot alkaline lye. The process of exposing and bucking is repeated 2 or 3 times until the fibre is white.

3d. *Cleansing,* by laying the goods in lukewarm water acidulated with sulphuric acid, and finally washing them thoroughly at the dash-wheel. Cotton loses about 5 per cent. of its weight in bleaching.

Theory. It is remarkable that we cannot yet explain the manner in which bleaching is performed, whatever process is pursued. In the present case, it is probable that air and moisture (arising from rain, dew, or artificial sprinkling), influenced by solar light, oxidize the color on the fibre, even without the assistance of alkali. But by exposure, the color becomes more soluble in alkali, and hence each successive bucking removes the portion decomposed. The final *souring* removes any earthy matters, which may have become attached to the fibre during

the process, and neutralizes the last portions of alkali, which would have been difficult to remove by water alone.

By the preparatory fermentation, the weaver's paste, containing starch and gluten, undergoes successively the saccharine, vinous, and acetous fermentation, by which gluten and other substances are dissolved in the acetic acid generated, and the fibre becomes swollen. Care must be taken to stop the operation before the putrefactive process commences, which would injure the fibre.

The above operations are sometimes slightly varied. To hasten and complete the fermentation, bran or rye-flour may be added to the steeping water. The addition of alkali or lime (which is sometimes used) lengthens the fermentation, and should only be used where it is too rapid. If the goods be greasy, fermentation, being injurious, is omitted, and they are then merely boiled some hours in water, and washed. A bath of milk of lime is sometimes given immediately after fermentation and before bucking, which materially assists the bleaching, but it acts injuriously, unless all the weaver's paste has been destroyed by fermentation and washing. At the present time nearly all the cotton of commerce is bleached by chlorine, the atmospheric agents being employed as very subordinate assistants.

Linen.

Flax, when not *retted*, contains but little coloring matter, which can be removed by a few washings with soap and alkali, but the putrefactive process of retting produces a color which requires a tedious series of operations to remove. To employ the chlorine process alone would undoubtedly shorten the time of bleaching, but the color adheres so pertinaciously to the fibre, and so obstinately resists decomposition, that the strength of the fibre would be impaired. Hence a tedious atmospheric bleaching is always resorted to for linen, combined to a limited extent with chlorine. Even with this process, the long exposure to light, air, and moisture, the oft repeated operations necessarily weaken the fibre, as may be inferred from the loss by bleaching, which may often amount to $\frac{1}{3}$ or 30 per cent. of the weight.

The process without chlorine, as practised in Silesia and Bohemia, consists of, 1st, steeping, exposure to light, &c., and washing; 2d, bucking, exposure, washing.

1st, *Steeping*. After fermentation and washing, the linen is steeped for 12 hours in a solution of potash or waste lye (1000 water to 1 or $1\frac{1}{2}$ lbs. potash) at the temperature of 70°–80°, wrung out, and, without being washed, spread out upon grass to the action of the air until dry, and for several hours after. It is again steeped and exposed to the air, the temperature of the solution being gradually raised at the last steeping, but not above 170°. The steeping and exposure being repeated 2 to 5 times, the linen is washed in the dash-wheel, steeped again 1 to 3 times in alkaline solution, and then properly bucked.

2d, *Bucking*. The bucking solution contains at first 4 lbs. potash to 1000 water, and the tem-

perature beginning with 95° is increased during 18 hours to boiling. The linen is then exposed to the air as before, while still hot, and wet with the solution until fully dry. This alternate bucking and exposure is repeated 8 or 10 times, the alkaline solutions being rendered a little stronger, but not exceeding 4 lbs. to the 1000 of water; the linen is then washed in the dash-wheel. It is again steeped and again bucked several times, the liquors employed being weaker, and the linen exposed on the grass for a longer time, and being kept moist by sprinkling.

Thus, after steeping 8–10 times, bucking 12–15 times, and as often exposing it, which operations require 60–70 days, the linen is sufficiently white for domestic use. But for a pure white, it is next passed through a bath acidulated with sulphuric acid, steeped, bucked 2–3 times more, and exposed, again passed through the acid, and finally cleansed in the dash-wheel. The whole process requires 80–90 days, and the linen loses from 12 to 25 per cent. of its weight, the less in proportion to its fineness.

Theory. The stem of flax and hemp consists of the inner woody part, or boon, surrounded by the harl like a fibrous sheathe, and externally the cuticle. The harl is united with the boon and cuticle by a cement of gluten, gum, resin, &c., which is destroyed by retting (putrefaction in water or moist air). When the retting is completed, the harl is easily separated from the others, but beside its natural color, it has received a deposit of a humus-like substance, of a more or less dark color, which is insoluble in boiling water, in acids, and alkalis. But when it has been exposed to the air, light, and moisture, it becomes soluble in caustic and carbonated alkali. The bleaching succeeds much better when the fibre, imbued with alkali, is exposed to the air, from which we infer that the alkali induces the formation of an acid from the coloring matter, but it is unknown whether it act by forming carbonic or a ternary organic acid. The operations consist simply of the decomposition of the color and its removal by alkali. But as the color exists in every part of the bundles of fibres, and in considerable quantity, its complete removal is only effected by frequent repetition of the operations.

II. BLEACHING BY CHLORINE.

This powerful bleaching agent might be and has been employed both in its gaseous state and in solution in water, but the former is inconvenient in use, acts unequally on the goods, and is too dangerous to the health of operatives. The latter is more easily regulated and less injurious, but the chlorohydric acid produced during bleaching may be a source of inconvenience. Hence chloritised alkali is preferred, as it develops chlorine in proportion as acid is made to act on it, is not detrimental to health, and offers alkaline base to neutralize the generated muriatic acid. Chloride of lime or potassa is employed, the former most usually. 1 pt. dry chloride of lime, as far as regards its bleaching salt, dissolves in 10 pts. water, but this would be too strong for bleaching white

grounds, and is only used for printing; this bleaching liquid may therefore be diluted with 5 or 10 times as much water. Chlorine bleaching is performed on cotton, linen, and rags.

Cotton.

Cotton bleached by chlorine is subjected to the successive action of, 1st, soda-lye, 2d, chloride of lime, 3d, sulphuric acid, all employed in dilute solutions. To remove the weaver's dressing, either fermentation or boiling with

milk of lime and souring are employed. If the goods are greasy, fermentation is abandoned and, indeed, boiling water and the lime-bath forms at present the usual preparatory step. The succession of separate processes is various, according to the nature of the goods, or their destined object, and according to the pleasure or experience of the bleacher. The following tabular views will present some of these differences:

- | | | |
|---------------------------------------|---------------------------------------|--------------------------------------|
| 1. Preparatory. | 1. Preparatory. | 1. Preparatory. |
| a. Washing. | a. Boiling with water. | a. Steeping in water. |
| b. Boiling in lime-water. | b. Washing. | b. Fermentation. |
| c. Washing. | c. Boiling in milk of lime. | c. Washing. |
| d. Souring. | d. Washing. | 2. Bleaching. |
| e. Washing. | 2. Bleaching. | a. Bucking with weak caustic potash. |
| 2. Bleaching. | a. Bucking in soda-lye. | b. Bucking with stronger lye. |
| a. Soaking in soda-lye. | b. Exposing on grass. | c. Chemicking. |
| b. Washing. | c. Washing. | d. Souring. |
| c. Chemicking. | 3. Same as 2, repeated once or twice. | e. Washing. |
| d. Souring. | 4. Finishing. | 3. The same as 2, repeated, or |
| e. Washing. | a. Souring. | a. Exposure on grass. |
| 3. The same as 2 repeated throughout. | b. Washing. | b. Souring. |
| 4. Finishing. | | c. Washing. |
| a. Soaking in hot water. | | |
| b. Squeezing and drying. | | |

Theory. In the preparatory process, the first steeping in hot or cold water removes whatever is soluble in water. The lime then dissolves the gluten of the paste, forms a lime-soap with grease, or the gluten is destroyed by fermentation. (See *Atmospheric Bleaching* above.) If the goods had been greasy, the fatty matter is removed by the following bucking in soda-lye. Thus cleansed, the goods are steeped for some hours in the bath of chloride of lime, or *chemicked*. The quantity of the bleaching salt varies in different establishments, and according to the goods; 100 lbs. of the latter require about 50 lbs. of chloride, which is first made into a paste with water, and then added to about 300 gallons water. From the chloride the goods are immediately transferred to the *sour*, or dilute sulphuric acid, consisting of one gallon of oil of vitriol to from 20 to 40 of water, in which they remain a shorter or longer time in proportion to the strength of the acid. The action of the acid is to develop chlorine from the bleaching salt with which the goods are imbued, and to neutralize and remove lime. The goods are washed, and the bleaching repeated, either by chemicking and souring, or by alkali and exposure, until sufficiently white.

Chloride of lime may be simply viewed, without reference to chemical theories, as chlorine gas combined with lime, so that the sulphuric acid, by combining with the lime, expels the chlorine, which is the cause of the destruction of the coloring matter in goods. But in what manner it decomposes the color has not been determined experimentally, although all chemists are agreed that it is by its affinity for hydrogen, forming chlorohydric acid. Berzelius holds that chlorine, with the action of light, or from the presence of oxidable substances, decomposes water, forming muriatic acid, while the oxygen set free combines with another portion of chlorine to chlorous acid, or

with water to binoxide of hydrogen; either or these yields up its oxygen to the color until all the chlorine is changed into muriatic acid. Others believe that the chlorine combines directly with the hydrogen of the color to muriatic acid; while some think it is substituted for the hydrogen. In any case, whether by oxidation, dehydrogenation, or substitution, the color is destroyed. But from the powerful action of chlorine, even when dilute, it cannot be continued for a long time, as it would destroy the fibre, as well as the color. Hence it is well adapted to cotton, whose color is easily removed, but it can only be employed as an assistant in linen bleaching, whose color more stubbornly resists decomposition.

Warmth assists the action of chlorine, but is apt to be injurious to the fibre. A little dilute sulphuric acid may be added to the chloride of lime when largely diluted with water, and is thought to hasten its action, from the formation of chlorite of lime or oxygenated water, which remain in the bath when dilute and cold. For it has been found that even when a sufficient quantity of acid is added to decompose nearly all the bleaching salt, in a dilute and cold bath, its bleaching power is undiminished or imperceptibly weakened after the lapse of some days.

Linen.

Chlorine and souring, with sulphuric acid, have been lately employed as an aid to the bleaching process of linen, and it would seem without injury to the fibre, which loses even less in weight than by the older process. The first steps are usually the same to about the 5th bucking, as shown in the following view of the process.

- 1, 2. Steeping in weak, warm lye.
- 3—7. Bucking, exposure, and washing.
8. Souring 12 hours in dilute acid, and washing.

- 9, 10. Steeping, bucking, &c.
11. Chemicking (chloride of lime), washing.
12. Souring and washing.
13. Bucking and exposure.
14. Chemicking, and washing.
15. Souring and washing.
16. Bucking and exposure.
17. Souring and washing.
18. Washed with soap, and thoroughly with water.

The chemic or bath of chloride of lime is sometimes employed but once, sometimes 3 times. Chloride of soda or potassa is frequently employed instead of lime. The linen is washed after being in the chlorine-bath, and previous to souring, for immediate souring after the bleaching salt weakens the fibre. The action is similar to that above (see under *cotton*), with this difference, that the chlorine is developed more slowly. By the assistance of chlorine the time of bleaching linen is shortened some 3 to 5 weeks.

Rags.

The sorted, cut, and dusted rags are thrown into a tight vat, in which they are boiled with milk of lime containing a little alkali to remove grease, loosen colors, &c., or interstratified with dry lime and a little alkali, are steamed. They are then washed in the engine (Hollander) and reduced to half-stuff, when the chloride of lime is thrown in and worked through the mass by the engine, the gates being closed. Dilute oil of vitriol is then let on the mixture and worked through in order to develop chlorine; after which the gates are opened, and, while reducing to fine pulp, the current of water removes the salts of lime. A solution strong enough to bleach dark-colored rags must weaken the fibre, to avoid which a second bath of chloride may be resorted to; by washing off the salts from the first, then passing a little alkali through, and adding chloride afresh, or immediately adding the latter after washing, and then souring and washing as before. When chloride is applied in two portions, a small quantity is used with less injury to the fibre. Muriatic acid may be substituted advantageously for sulphuric, from the greater solubility of chlorides over sulphates. To prevent paper from becoming yellow, after bleaching and washing off the salts of lime, work a little alkali through the engine, with the gates down, and wash off the residue with water. The principles are the same as explained above under the bleaching of *Cotton* by chlorine.

III. SULPHUROUS BLEACHING.

The vapor of burning sulphur is employed for removing color from, or whitening wool, silk, and straw.

Wool.

Neither chlorine nor atmospheric bleaching can be employed for wool, as they rather render it dirty yellow. Wool contains a greasy coating, called the *yolk* (Schweiss, Suint), arising from the sweat of sheep, which is composed of a potash soap, together with acetate, carbonate, and muriate of potassa, a salt of lime, and an animal substance, the cause of its pe-

culiar odor. The greater part of the yolk is soluble in water, but alkali removes it more perfectly. It is usual to employ putrid human urine, diluted with 4 to 8 times as much water, warmed to 100° or a little more, into which the wool is steeped for a short time, taken out, drained, and washed. The yolk may also be removed by weak and warm soap-water, or a little very dilute carbonated or caustic potassa or soda, or both soap and a little alkali; but the use of alkali requires more care, lest the fibre should be attacked, and hence it is only used, if at all, for inferior kinds of wool. A continuance in the urine or alkali, and too high a temperature, injure woollen fibre. The loose wool should not be worked about too much, which would cause it to felt, and thereby injure it for spinning.

After washing, the bleaching is performed by exposing the moistened wool in a close chamber to the vapor of burning sulphur, or it is steeped in water acidulated by sulphurous acid. The latter solution is made by passing sulphurous acid gas, derived from oil of vitriol and charcoal, into water (see *SULPHUR*). Sulphuring by the gas of burning sulphur is more commonly practised, and is more economical, but the liquid acid, while it bleaches equally well, renders the wool less harsh and crisp, and does not injure the fibre. It is exposed to the gas for 12 to 24 hours, to the liquid acid 24 to 48 hours. The harshness derived from sulphuring is removed by soaking the wool in a warm and weak bath of potash-soap, wringing, and drying. To impart a more brilliant white, the bleached wool is sometimes dipped into chalk-water.

Wool is sometimes bleached in the fleece, and sometimes in the yarn. Both yarn and cloth are cleansed in a manner similar to the above by alkali or soap, in order to remove grease and glutinous matter derived during spinning and weaving. Cloths may be cleansed in the wash-stocks, with fuller's earth, or a soap containing it.

Silk.

The bleaching of silk is of a simple nature. This fibre is coated with a gelatinous substance, a little wax, oil, and generally a yellow coloring matter; and is therefore essentially different from *gum*, as it is usually called. The gluey material, often constituting 24 per cent. of the weight of the silk, is soluble in water, scarcely in boiling alcohol, precipitable by tincture of galls, putrefies like animal matter, and its odor, when heated, indicates the presence of nitrogen. The yellow coloring substance, constituting nearly 2 per cent. of the silk, is of a resinous character, insoluble in water, very soluble in alcohol, scarcely soluble in cold, more in warm alkali, and still more in a hot solution of soap, is decolorized by chlorine, sulphurous acid, and in a few days by the atmosphere.

The coating imparts a stiffness and elasticity to silk, which must be removed in order to impart to it its requisite softness and lustre. Although alkali has been proposed and employed to remove the coating, it is found that scouring by soap, used long since, cannot be

BLEACHING.

well superseded. From 30 to 40 lbs. of soap to 100 lbs. silk are usually required. The greater part of the soap is dissolved in boiling water, and when cooled a little, the silk is hung over and partly immersed in the solution, which is maintained below a boiling heat, until the immersed part has attained its requisite whiteness and softness, when the other portion is next introduced in like manner. After being wrung out it is next put into bags, which are introduced into a weaker solution of soap, in which they are boiled for an hour or more. For silks designed to receive dark dyes, 20 to 25 lbs. soap will be sufficient.

Silks designed to be of a pure white are subjected to the action of sulphurous acid by exposing them in a sulphur chamber to the fumes of burning sulphur, while still moist with soap-water. After sulphuring, they are washed, and passed through a warm soap-bath, in order to remove the sulphurous odor and restore their pliancy.

Silk designed for blonds, gauzes, &c., are merely stripped of their yellowish color by steeping them for two days in alcohol with $\frac{1}{32}$ as much muriatic acid; a process proposed by Beaumé, which can be conducted economically, since a large proportion of the alcohol may be recovered by distillation after neutralizing the muriatic acid by chalk or limestone. Alcohol removes color, wax, &c. without touching the gelatine.

Straw.

A careful culture insures a requisite degree of fineness and firmness in the material, but for most purposes the color must be diminished or removed. This may be done by chlorine, sulphurous acid, alkali, or atmospheric agents, but a violent process injures the fibrous texture. It may be steeped in pure fresh water for several weeks, exposed to the air, and then sulphured. According to Kurrer, it may be perfectly whitened by repeated steeping in boiling water and very weak alkali, which removes all soluble matter, then treated alternately with very dilute solutions of chloride of lime and sulphurous acid vapor, finally washed and dried in the sun. The process is tedious, but is said to remove the varnish which makes the natural straw brittle, and to render the fibre brilliant, white, and pliant.

Theory. It is even more difficult to explain the bleaching process by means of sulphurous acid than that by chlorine. It is generally assumed that the acid combines directly with the color, without either giving or receiving oxygen, and forms a colorless or slightly colored compound with it; for by the action of alkali or a stronger acid, the original color is restored; and hence, also, the color reappears on sulphured goods in the lapse of time by the gradual dissipation of sulphurous acid. The action of alkali in the above operations with wool, silk, and straw, depends simply on the solubility of the coloring or other matters in the alkaline solution.

IV. DISCHARGES.

There are many operations practised by the calico-printer, which may be termed bleaching, although they consist only in a topical removal

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or discharge of color. Thus chromic acid, or bichromate of potassa, or the chlorides of tin are employed to discharge colors, but their action has not been minutely studied. It is probable that chromic acid yields up oxygen, destroying the color by oxidation, and that the tin-bases form with the coloring matters compounds possessing little or no color. But their action is different on different colors, and the protoxide of tin decomposes some colors by abstracting oxygen. (See CALICO-PRINTING.) In short, wherever we destroy color, with the view of obtaining a white basis or ground, it is, strictly speaking, a bleaching operation. Thus a liquid may be decolorized by passing it through animal black, which absorbs the coloring matter (see SUGAR). Some oily substances may be whitened by sulphuric acid, and some again by nitric acid, the former carbonizing, the latter oxidizing the coloring substance.

BLEACHING POWDER. Syn. Bleaching salt, Chloride of lime; *Ger.* Bleichkalk, Bleichpulver, Chlorkalk; *Fr.* Chlorure de chaux. This being the most important of the bleaching salts, its manufacture will be here treated of, referring for theoretic views to CHLORINE. Its manufacture depends on the absorption of chlorine gas by slacked lime, and consists: 1st, of the preparation of lime; 2d, of that of chlorine; and, 3d, of the combining the two together.

1. *Lime.* Limestones frequently contain iron, clay, and magnesia. (See remarks at the close of BITTER SPAR.) Such are not well adapted to the manufacture of bleaching powder. Supposing the limestone to be of the best kind, and well burned (see *Lime* under CALCIUM), the operation of slacking requires some attention, for just so much water should be used as is sufficient to cause the quick-lime to fall to a fine flour. It is likewise important that the lime should be fresh, for otherwise it will have absorbed carbonic acid from the air and have become proportionally injured. In order to effect the perfect slacking, it is perhaps better to add a little less than a little too much water.

2. *Chlorine.* This gas may be made either with black oxide of manganese and muriatic acid, or with the same oxide, and common salt with sulphuric acid. The manganese ore should contain as much pyrolusite and as little manganite as possible, since the former contains much more oxygen, which is required to oxidize the chlorohydric acid and develop chlorine. To determine the value of the ore, see MANGANESE ORES. The ore is reduced by calculation to binoxide. The ore is coarsely pulverized, for if in fine powder it is apt to form a compact mass at the bottom of the vessel for generating chlorine. For every 44 pts. of binoxide present in the ore, 58 pts. dry common salt are required, which are well mixed with the ore, and the whole thrown into a leaden vessel or generator; 140 pts. sulphuric acid, diluted with as much water, are then poured into the generator.

The generators, or retorts for generating chlorine, are in some cases made entirely of lead, in others of two hemispheres, joined together in the middle, the upper hemisphere being lead, the under one cast-iron. The first

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kind, Pl. V. fig. 9, is enclosed for two-thirds from its bottom, in a leaden or iron case, the interval of two inches between the two being destined to receive steam from an adjoining boiler through the pipe *a*. Those which consist below of cast-iron, have their bottom directly exposed to a very gentle fire; round the outer edge of the iron hemisphere a groove is cast, into which the under edge of the leaden hemisphere fits, the joint being rendered air-tight by Roman or patent cement. In this leaden dome there are four apertures, each secured by a water-lute. The first opening, *b*, is about 10 or 12 inches square, and is shut with a leaden valve, with incurvated edges, that fit into the water channel at the margin of the hole. It is destined for the admission of a workman to rectify any derangement in the apparatus of rotation, or to detach hard concretions of salt from the bottom.

The second aperture, *c*, is in the centre of the top. Here a tube of lead is fixed, which descends nearly to the bottom, and through which the vertical axis, *d*, passes. To its lower end the cross bars of iron, or of wood, sheathed with lead, are attached, by whose revolution the materials receive the proper agitation for mixing the dense manganese with the sulphuric acid and salt. The third opening, *e*, admits the syphon-formed funnel, through which the sulphuric acid is introduced; and the fourth, *f*, is the orifice of the eduction-pipe, *g*. The residue, after being exhausted of chlorine, is drawn off by the pipe *h*. The pipe *g*, is conveyed into a leaden chest or cylinder, *i*, in which all the other eduction-pipes also terminate. They are connected with it simply by water-lutes, having a hydrostatic pressure of 2 or 3 inches. In this the chlorine is washed from adhering muriatic acid, by passing through a little water, in which each tube is immersed, and from this the gas is let off by a pretty large leaden tube, *k*, into the combination-room. It usually enters in the top of the ceiling, whence it diffuses its heavy gas equally round.

Four days are required, at the ordinary rate of working, for making good marketable bleaching-powder. A more rapid formation would endanger an elevation of temperature, productive of muriate of lime, at the expense of the bleaching quality. But skillful manufacturers use an alternating process, by piling up the wooden trays containing slacked lime only in alternate shelves in each column. At the end of the two days the distillation is intermitted, and the chamber is laid open. After two hours the workman enters, to introduce the alternate trays covered with fresh hydrate of lime, and at the same time rakes up thoroughly the half-formed chloride in the others. The door is then secured, and the chamber, after being filled for two days more with chlorine, is again opened, to allow the first set of trays to be removed, and to be replaced by others, containing fresh hydrate, as before. But for this judicious plan, as the hydrate advances in the impregnation, its faculty of absorption becoming diminished, it would be requisite to diminish proportionately the evolution of chlorine, or to allow the excess to escape to the great loss of the proprietor, and, what is of more conse-

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quence, to the great detriment of the health of the workmen. (*Ure.*)

Instead of admitting the chlorine into a chamber, it may be conducted into cylindrical vessels of stone-ware, *m*, Pl. V. fig. 9, through inverted leaden funnels, *l*, the lower rim of which has a waved outline in order to favor the escape of the gas. The hydrate of lime is shaken loosely into the vessel around the funnel, the vessel covered with a wooden cover, and the chlorine passed into it. 26—30 such vessels are enclosed by low walls, and in order to keep the temperature low, are surrounded with cold water, so that the temperature in the interior of the pots does not exceed 110°. The chloride of lime made in pots is much harder and denser than that made in chambers.

A good dry chloride of lime should be a white, uniform powder, possessing a faint odor of chlorine, *slowly* deliquescent in the air, forming a smooth paste with a little water, and dissolving in 20 pts. water with little residue, which solution should react alkaline. It should always have an excess of lime to protect it as far as possible from decomposition, and to neutralize free muriatic acid, which may be generated.

A liquid chloride is often preferred to the dry powder by many calico-printers, especially where it is manufactured in their own establishment. The arrangement above given may be employed for liquid chloride by passing the chlorine through tubes into milk of lime, consisting of 3 or more pts. lime to 100 water. The tubes should not dip deeply in the liquid, and the milk should be stirred up frequently. This solution of chloride tests stronger than the dry chloride from an equal quantity of lime, but, *per contra*, it is more liable to decomposition and must be used a short time after its preparation. For the theoretic view of the chemical constitution of chloride of lime, see CHLORINE; and for determining its bleaching value, see CHLORIMETRY.

BLLENDE. *Min.* Syn. Dodecahedral Garnet-Blende, *Mohs*; Black Jack; Sulphuret of Zinc. *Descrip.* Crystal. system, Regular; in form of cube, 12-hedron, or these combined with the 8-hedron; the 12-hedron is the predominating form; hemiform of the $\frac{9}{2}$ hedron is sometimes observed. A singular combination is frequently met with the 12-hedron and $\frac{24}{2}$ hedron in equilibrium; more rarely this combination includes other forms, which render it extremely complex. It is sometimes compounded, the plane of revolution being parallel to an octahedral face. B. cleaves perfectly parallel to the 12-hedron. It also occurs botryoidal, mamillary, in small detached spheres and other imitative shapes; amorphous with granular structure.

H. = 3·5 — 4. G. = 4 — 4·15.

Color black, brown, red, yellow, green, sometimes almost colorless with a yellowish tint, lustre adamantine, resinous; translucent, transparent; fracture conchoidal; brittle; streak reddish brown, white.

Behavior. Sometimes decrepitates violently, is rounded slightly on thin edges, and gives traces of sulphurous acid; on charcoal in the

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exterior flame it produces a coating of oxide; soda reduces it. Dissolves in strong nitric acid, leaving sulphur.

Analysis. 1. By Arfvedson; 2, a lamellar brown variety from Luchon in the Pyrenees by Berthier; 3, fibrous, from Przibram, Bohemia, average of two analyses by Löwe.

	1.	2.	3.
Zinc.....	66.34	63.0	62.01
Iron.....	—	3.4	2.25
Cadmium.....	—	—	1.64
Sulphur.....	33.66	33.6	32.95
	100	100	98.85

In its pure state its formula is ZnS , to which

	1.	2.	3.	4.	5.	6.
Sulphuret of zinc.....	75.5	63.4	82.76	67.00	77.5	76.8
Sulphuret of iron.....	17.2	11.6	13.71	19.86	22.5	23.2
	92.7	75.0	96.47	86.86	100	100

BLOCK TIN. *Tech.* This term was formerly applied exclusively to solid metallic tin, but it is also applied at present to sheet-tin, with a thicker coating than ordinary of metallic tin.

BLOEDITE. *Min.* See **POLYHALITE.**

BLOOD. The fluid which circulates in the animal body in certain vessels, called blood-vessels. In vertebrated animals it is of a red color in the greater vessels, but colorless in their minute ramifications. The blood of the lower classes of animals is, with few exceptions, colorless.

In the higher classes of animals, that blood which is brought to the heart from the lungs, and projected through the arteries from its left ventricle into all parts of the body, has a brighter red color, and is called arterial blood; that which is returned from all parts of the body through the veins to the heart and thrown from its right ventricle into the lungs, has a dark red color, and is called venous blood. The difference in the color of these two seems to depend on an absorption of oxygen in the lungs, but the color of the venous blood may be changed into that of arterial by other substances incapable of producing any chemical change in it, as several salts of the alkalies, sugar, &c. Both varieties of blood seem not otherwise to vary materially from each other.

Blood of mammalia and birds forms an opaque, slightly viscid, red liquid of 1.0527 to 1.057 spec. grav., of a saline disagreeable taste, and feeble but peculiar odor. Examined under the microscope, it is seen to consist of a number of small red particles, commonly called blood-globules, floating in a clear, colorless, or slightly yellowish fluid, liquor sanguinis. In mammalia the red particles, or blood corpuscles, form circular disks, more transparent in the middle than at the edges, and appearing under the microscope not red, but only of a darker color than the fluid in which they float. Besides these, other, but less numerous and smaller bodies are observed of a roundish, but less regular form, and of a granular appearance, which are called lymph globules.

BLOOD.

1 approaches. Several have been examined, in which the quantity of protosulphuret of iron is considerable. 1, from Cogolin, and 2, from Argentiére, France, by Berthier; 3, from Cherone, France, by Lecanu; 4, from Cabrera, Eastern Pyrenees, by Bouis; 5 and 6, black blendes, from Marmato (hence Marmatite) near Popayan, by Boussingault.

In the 2d and 4th the impurities are omitted. For 1, 4, 5, and 6 the formula is nearly $3\text{ZnS} + \text{FeS}$.

Localities, &c. B. occurs in metamorphic and secondary rocks, usually associated with galena, and rarely alone; also with copper pyrites, heavy spar, sparry iron, red hematite, &c. Its localities are therefore numerous both in Europe and the United States.

When blood, either arterial or venous, is withdrawn from circulation in the body, it soon coagulates and forms a clot, which gradually contracts more and more, and then floats in a clear yellowish or greenish liquid called the serum. This coagulation is not prevented by any extraneous circumstances, such as temperature, exclusion of the air, &c., and it takes place in the blood-vessels themselves as soon as the circulation is interrupted, and used therefore to be ascribed to the loss of an innate vitality. The coagulation depends on a content of fibrin, which is kept in solution in the blood, but on its coagulation separates and encloses at the same time the red globules and other particles kept in suspension in the blood, thereby forming the coagulum, or clot, which subsequently contracts more and more. If the blood be whipped while drawn, the fibrin coagulates on the whip, and is thereby prevented from enclosing the red particles of the blood, which remain in suspension, and the blood then retains its usual appearance without further coagulation.

If blood be received in water, the envelope and the red coloring matter of the blood-globules dissolve in the water, and their colorless nuclei remain in suspension in the liquid. Coagulation is in this case prevented by the addition of water, by which the fibrin is kept in solution. Coagulation of the blood may also be prevented by the addition of a small portion of hydrated soda or potassa ($\frac{1}{1000}$), which is a powerful solvent for the fibrin. It may further be prevented by the alkaline carbonates and some other salts, but of which a much larger amount is required.

In the serum the red globules remain without change. The same is the case if the serum be diluted, instead of water, with a weak solution of sugar, or of certain salts. If blood be mixed with 8 times its volume of a saturated solution of Glauber's salt, coagulation is prevented, and at the same time the globules remain undissolved, and settle after some time to the bottom of the vessel, and may then be separated by filtration, which could not be done with fresh

blood on account of its slimy character. In the former case, the globules remain on the filter as a magma, owing to their pulpy consistence, when saturated with water. Dissolved fibrin seem to have considerable influence in disposing the globules to settle.

The main proximate constituents of the blood are: fibrin, albumen, globulin, and hematin. Of these, the fibrin and albumen occur in solution, while the globules are formed of globulin and hematin (coloring matter). On coagulation, the fibrin separates and encloses the globules, which, together, form the clot, while the albumen remains in solution and forms the main ingredient of the serum. Fibrin, albumen, and globulin resemble each other so much in their chemical properties that a similarity in their composition was long suspected, till at last the Holland chemist, Mulder, proved that they all contain one and the same organic substance, but modified by the different chemical processes in the body, and combined with different quantities of inorganic substances (sulphur and phosphorus). This substance Mulder considered as the basis of all the other substances contained in the blood and used for the nourishment of the body and the performance of its other chemical processes, or as the *prima materia*, and called it, for this reason, *protein* (from *πρωτεω*, to be the first).

For the chemical properties of *protein*, its separation and its relation to the different animal substances, &c., &c., we refer to **PROTEIN**.

The *fibrin* is dissolved in the blood, but precipitates, as we have seen, when the blood is withdrawn from the circulation. It thus forms a kind of fine net or cell-work, which encloses the blood-globules and forms the *coagulum* or *clot*. The size of the latter depends, therefore, mainly on the quantity of the red globules, the quantity of fibrin being always small, amounting only to about $\frac{1}{3}$ or $\frac{1}{2}$ per cent. of the blood. For fibrin, we refer to article **FIBRIN**.

We have already mentioned how the *globules* might be separated from the blood. The red globules of the blood are formed of two substances, *hematin* and *globulin*. Of these, the former is the substance to which the blood is owing its red color. For the separation of these two substances, and their chemical character, see **HEMATIN** and **GLOBULIN**. The latter substance has great resemblance to albumen, with which it, for a long time, was confounded. When the red globules of the blood are dissolved in pure water, their nuclei remain undissolved, as extremely small colorless globuli, which, in the mammalia, are too small for examination, but in the frog may be collected and examined. These nuclei seem not to be formed of a substance resembling albumen, as they neither swell up nor dissolve in acetic acid, but their true nature has not yet been fully investigated.

Albumen is contained in the serum, which is mainly a solution of it in water. The serum forms a yellowish, sometimes greenish or reddish yellow liquid, of a saline disagreeable taste and an alkaline reaction, and has a spec. grav. of 1.027 to 1.029. It forms about $\frac{3}{4}$ of the weight of the blood, while the clot in its moist (not pressed) state forms about $\frac{1}{4}$. In the serum

the albumen is combined with fat and with soda, to which it owes its alkaline reaction, and with phosphate of lime. If the serum be heated to 169°, it is converted into a jelly-like mass from the coagulation of the albumen, without the extrication of any gaseous substance. For the chemical properties of albumen see under **ALBUMEN**.

Fatty matters in the Blood. Both the clot and the serum contain several fatty matters, which occur in the blood, partly dissolved as fatty acids in combination with bases, and partly suspended as globules. When blood coagulates spontaneously, the clot encloses the suspended particles of fat, which may be extracted with alcohol or ether, but a portion remains in solution in the serum, from which a great portion of it may be abstracted by shaking with ether.

It is probable that the blood contains all the different fats contained in the body. Berzelius examined the fat, which may be extracted by alcohol or ether from the fibrin after its coagulation from ox-blood. In its melted state it is yellow, but becomes solid and crystalline on cooling. It contains no phosphorus, but leaves an alkaline ash, and its solution in alcohol reddens litmus-paper. It is therefore precipitated in its saponified state as an acid salt. By digestion with caustic potassa a portion of it remains undissolved as a white powder.

Boudet examined the fat, which may be extracted from dried blood by boiling alcohol, after completed extraction with water, after which the blood is again dried and repeatedly treated with boiling alcohol. After filtration, the boiling-hot alcohol deposits, on cooling, a solid fat in flocks, which, by Boudet, has been named *serolin* (from *oleum* oil and *serum*).

Serolin is thus obtained as flocks of a pearly lustre, and unctuous to the touch. At 97° it melts, and may almost be distilled without change, yielding, however, at the same time, ammoniacal vapors of a peculiar characteristic odor. It is lighter than water, and is not capable of forming an emulsion with it. It is insoluble in alcohol of 0.833 spec. grav., in which it only dissolves very sparingly by boiling, and separates again on cooling. Easily soluble in ether. Is not saponified by alkalis.

The alcoholic solution, from which the *serolin* has deposited, leaves, on evaporation, a mixture of several fatty matters. On treatment of this with cold alcohol of 0.833, a white crystalline fat remains, which contains phosphorus, and seems to be identical with some of the fatty matters of the brain. The alcoholic solution deposits, on evaporation, cholesterol in foliated crystals, and leaves at last a mixture of oleic and margaric acids combined with a small portion of alkali.

In serum Lecanu detected cholesterol, *serolin*, and fatty acids, but no fat containing phosphorus.

It seems to follow from the foregoing, that both albumen and fibrin is accompanied by peculiar fats containing no phosphorus, and that the latter variety of fat, therefore, must belong to the red globules of the blood.

After coagulation of blood, or of serum, by heat, the *remaining liquid* contains, besides dif-

ferent inorganic salts, several organic matters, the amount of which, however, is not great, and a portion of which may be formed by the action of the water by heat on the albuminous substances during the coagulation. On evaporation to dryness in a water-bath, an extractive mass is left, with distinct crystals of chloride of sodium. Anhydrous alcohol extracts only a very small portion of a yellowish substance, after which alcohol of 833 dissolves chlorides of potassium and sodium, lactate of soda, and several other animal matters of an extractive nature, similar to those occurring in flesh and urine. After neutralization of the carbonated alkalies, in the residue, by acetic acid, and extraction of the acetates by alcohol, water dissolves phosphate and sulphate of the alkalies, and an animal substance precipitable by tannin, after which a small portion of coagulated albumen only remains undissolved.

Salts of the Blood. It has already been stated that the albumen exists in the blood in actual combination with *soda*. The latter base, with a small quantity of *potassa*, is also found in the blood in combination with fatty acids, and with smaller or greater quantities of lactic, carbonic, sulphuric, and phosphoric acids. It has also been mentioned that the blood contains a considerable quantity of chloride of sodium. The existence of *ammonia* in fresh blood is uncertain. *Lime* occurs also in the blood in combination with phosphoric acid, as phosphate of lime, with a small quantity of phosphate of magnesia. These earthy phosphates exist in combination with the albuminous ingredients of the blood, which keep them in solution, and with which they remain in combination after their coagulation. The *gaseous* ingredients of the blood, see under *RESPIRATION*.

Besides the above mentioned usual ingredients of the blood, it occasionally contains others which are accidental, either taken up by the digestive organs or from vitiated or suppressed secretions. These are, however, often excreted again so fast that their detection is difficult.

Analysis and Composition of Blood. The quantitative estimation of the different constituents of the blood often becomes a matter of interest in a physiological or pathological point of view. Berzelius prescribes the following method: two quantities of the same blood are weighed, and one allowed to coagulate spontaneously, the other is evaporated in a water-bath to perfect dryness, and the residue weighed, which, deducted from the original weight of the blood, yields the amount of *water*.

The coagulum of the first portion, when sufficiently contracted so as to float freely in

the serum, is removed, cut to pieces if too large, laid between two counterpoised filters, and pressed between folds of blotting paper, which are to be renewed without removing the counterpoised filters. When all the serum has been thus absorbed, the clot is dried without removing it from the filters in *vacuo* over sulphuric acid, and weighed with proper precautions to prevent it from absorbing moisture from the air. After deduction of the weight of the filters, this yields the *amount of fibrin and blood-globules*; the latter are then extracted by repeated treatment with water of a temperature of from 77° to 86° till it becomes no longer colored, when the fibrin which thus remains is dried and weighed. It may sometimes be more convenient not to employ the whole clot, but only a weighed portion of it. Thus the *relative proportion of fibrin and blood-globules* is obtained. In the aqueous solutions the globulin and hematin of the blood-globules are contained, and may be separated from each other, as indicated under these heads.

The other weighed portion of the blood, which has been evaporated to dryness, is pulverized and treated first with ether, and then with alcohol, and at last with boiling-hot water. The residue thus left yields, when dried (as before), the amount of all the albuminous ingredients of the blood, from which the weight of the *albumen* is obtained by deducting that of the fibrin and blood-globules. The ethereal solution contains the fat, the amount of which is determined after evaporation of the ether. The alcoholic and aqueous solutions contain the salts and the other less important organic substances of the blood (extractive).

For the *analysis of the serum*, the latter may be coagulated by heating it to 170°, evaporating it in a water-bath to dryness, pulverizing, and then extracting, first with ether to dissolve fat, and then with boiling water, by which the albumen remains undissolved. The aqueous solutions are evaporated to dryness, and the residue treated with alcohol, which dissolves chlorides of potassium and sodium with lactate of soda and extractive. The residue from the alcohol, which ought to be perfectly soluble in water, is alkaline; neutralized with acetic acid, and again evaporated to dryness and extracted with alcohol, the latter dissolves acetate of soda, which, on incineration, is converted into carbonate. The residue from the alcohol is small, and contains phosphate of soda with a small portion of an animal matter, soluble in water, and precipitable by solutions of galls and chloride of mercury.

According to Berzelius's analysis, *serum* consists of:

	Serum from the ox.	From man.
Water.....	90.50	90.59
Albumen.....	8.00	8.00
Substances soluble in alcohol.....	0.88	1.00
Albumen, with soda and lactate of soda ..	0.62 }	0.4 }
Chloride of potassium	0.26 }	
Substances insol. in alcohol, soluble in water, animal matter, and phosphate of the alkalies.....	0.15	0.41
	100.00	100.00
		345

BLOOD.

These results agree well with those of Marcet and Lecanu's analyses of serum from human blood.

	Marcet.	Lecanu.	
		1.	2.
Water.....	90.000	90.600	90.100
Albumen.....	8.680	7.800	8.120
Extractive, including lactates.....	0.400	0.379	0.460
Chlorides of potassium and sodium.....	0.660	0.600	0.552
Carbonate of soda, with phosphate and sulphate of soda.....	0.200	0.210	0.200
Phosphates of lime and magnesia.....	0.060	0.071	0.087
		Fat 0.220	0.340
	100.000	99.900	99.859

The relative proportion of the *coagulum* and the *serum* of human blood is, according to Lecanu, Clot (dried) 13.085 (varying from 11.59 to 14.85) Serum 86.915

The *clot* consists, according to him, of:

Fibrin	0.295
Hematin	0.227
Albumen (globulin).....	12.568
	13.090

From this, and the analyses of the serum, he calculated the composition of the blood as follows:

	1.	2.
Water.....	78.015	78.559
Fibrin.....	0.210	0.356
Albumen	6.509	6.942
Blood-globules.....	13.300	11.963
Crystallizable fat.....	0.243	0.430
Oily fat	0.131	0.227
Extractive, soluble in alcohol.....	0.179	0.192
Substances only sol. in water.....	0.126	0.201
Salts of the alkalies.....	0.837	0.730
Salts of earths and ox. of iron.....	0.210	0.141
Loss.....	0.240	0.259
	100.000	100.000

Lecanu found that blood of females contains more water, the amount of which is also more variable. In 10 analyses of blood of females he found the amount of water to vary between 79 and 85½ per cent., while in the same number of analyses of blood of males it varied between 77.9 and 80½ per cent. Between twenty and 60 years the amount of water does not seem to be influenced by the age. The amount of albumen varies from 5.8 to 7.8 per cent., and does not seem to be influenced by sex or age. The red globules of the blood vary in the female between 6.8 and 13 per cent., in the male between 11.6 and 14.8. After sustained loss of blood, and in females, after menstruation, the amount of red globules is considerably less. The amount of salts varies between 0.08 and 0.014 per cent.

Denis has derived the following results from 83 analyses, carefully performed, showing the maximum and minimum of each of the chief constituents of the blood:

MALE.				
	Maximum.	Minim.	Variation.	Mean.
Water.....	80.5	73.20	7.30	76.7
Albumen.....	6.3	4.85	1.45	5.7
Blood-globules.....	18.6	11.05	7.55	14.9
Fibrin.....	0.4	0.20	0.20	0.275

BLOOD.

FEMALE.

Water.....	84.80	75.00	9.80	78.70
Albumen.....	6.84	5.00	1.84	5.90
Blood-globules.....	16.71	7.14	9.57	12.77
Fibrin.....	0.31	0.20	0.11	0.26

The blood of the *vena porta* is said to vary in some points from common venous blood by being, according to Schultz, of a darker color, its color being not affected by oxygen nor by the addition of salts, and yielding no coagulum, or only one that is white and diffused, which again disappears after 12 to 14 hours, separating into a clear liquid and a brown sediment. It contains more water than venous blood, and a less proportion of albumen, but a considerably larger amount of fat, amounting, according to him, to 1.66 per cent., while common venous blood only contains 0.83.

The following table exhibits the results of the analyses of Dumas and Prevost of blood from different animals. The size of the blood-globules are given in fractions of millimeters.

	Blood in 100 pts.			Serum in 100 pts.		Diameter of blood-globules.
	Blood-globules	Albumen	Water	Albumen	Water	
Man	12.92	8.69	78.39	10.0	90.0	$\frac{1}{150}$
Monkey ..	14.61	7.79	77.60	9.2	90.8	$\frac{1}{120}$
Dog	12.38	6.55	81.07	7.4	92.6	$\frac{1}{150}$
Cat.....	12.04	8.43	79.53	9.6	90.4	$\frac{1}{171}$
Horse....	9.20	8.97	81.83	9.9	90.1	$\frac{1}{200}$
Calf.....	9.12	8.28	82.6	9.9	90.1	$\frac{1}{200}$
Sheep....	9.35	7.72	82.93	8.5	91.5	$\frac{1}{200}$
Goat.....	10.20	8.34	81.46	9.3	90.7	$\frac{1}{200}$
Rabbit....	9.38	6.83	83.79	10.9	89.1	$\frac{1}{150}$
Guinea-pig.....	12.80	8.72	78.48	10.0	90.0	$\frac{1}{150}$
Raven....	14.66	5.64	79.70	6.6	93.4	$\frac{1}{80}, \frac{1}{150}$
Heron.....	13.26	5.92	80.82	6.8	93.2	$\frac{1}{80}, \frac{1}{150}$
Duck.....	15.01	8.47	76.52	9.9	90.1	$\frac{1}{70}, \frac{1}{150}$
Chicken ..	15.71	6.30	77.99	7.5	92.5	$\frac{1}{81}, \frac{1}{150}$
Pigeon	15.57	4.69	79.74	5.5	94.5	$\frac{1}{73}, \frac{1}{150}$
Trout	6.38	7.25	86.37	7.7	92.3	$\frac{1}{70}, \frac{1}{150}$
Barbot....	4.81	6.57	88.62	6.9	93.1	$\frac{1}{75}, \frac{1}{123}$
Eel.....	6.00	9.40	84.60	10.0	90.0	$\frac{1}{82}, \frac{1}{115}$
Land turtle.....	15.06	8.06	77.88	9.6	90.4	$\frac{1}{48}, \frac{1}{77}$
Frog.....	6.90	4.64	88.46	5.0	95.0	$\frac{1}{45}, \frac{1}{75}$

From the above table it appears that the blood of birds is richest in red globules, and that among the mammalia the blood of carnivorous animals contains more of them than

that of herbivorous, and that cold-blooded animals contain them in the least quantity.

Dumas and Prevost found that *arterial blood* contained about one per cent. more of blood-globules than *venous blood*, which, however, is not probable, on account of the difficulty with which the formation of the blood-globules is attended under other circumstances. According to some late investigations of Mulder, it seems probable that most of the fibrin exists in the arterial blood in an oxidized state (as oxyprotein, see under *FIBRIN*), but is again returned to the venous blood as fibrin.

Simon has performed a series of analyses of blood, the result of which are exhibited in the following table. (*Berzel. Arsb.* 1841.) He determined the amount of fibrin, by receiving the blood in a bottle containing pieces of metal, which had been previously weighed separately, and with the bottle, when the whole was again weighed after the reception of the blood into it. By shaking the blood in the

bottle the fibrin coagulated on the metallic fragments, and was then washed, dried, and weighed with them, and the fat subsequently extracted by ether. A portion of the blood thus freed from fibrin was coagulated, evaporated to dryness, weighed, pulverized, freed from fat by ether, and the remainder boiled from 5 to 8 times with alcohol of 50 per cent. till it no longer became colored. The residue of *albumen* was then dried and weighed. The alcoholic solution, which becomes turbid on cooling, is freed from alcohol by distillation, after which the solution is separated from the precipitate, and again, if necessary, precipitated by alcohol. The obtained precipitates, consisting of globulin and hematin, are then separated from each other by boiling with alcohol acidulated with sulphuric acid, which leaves sulphate of globulin, and dissolves sulphate of hematin. The solution from which the alcohol has been distilled is evaporated to dryness, and the residue weighed.

Blood.	Water.	Solid residue.	Fibrin.	Fat.	Al umen	Globulin.	Hematin	Extrac-tive and salts.
Male 17 years of age, in health,.....	721.900	208.100	2.011	1.978	75.590	105.165	7.181	14.174
Female 28 years of age, in health,.....	798.656	201.344	2.208	2.713	77.610	100.890	5.237	9.950
Girl 2½ years of age	757.831	242.269	—	3.393	109.080	106.650	8.726	14.500
Female 40 years old, with pneumonia,.....	839.848	160.152	9.152	2.265	100.415	34.730	1.800	8.003
Male “ “ “ “	803.179	196.821	5.632	4.336	121.721	52.071	2.752	10.309
Male 60 years, with beg. phthisis.....	803.404	195.009	3.443	0.697	102.100	74.948	2.466	11.258
“ 50 years, with diabetes.....	794.663	205.337	2.432	2.010	114.570	66.330	5.425	11.570
Female 20 years, with diabetes.....	789.490	210.510	2.370	3.640	86.000	38.500	5.100	14.900
Male 40 years, with Morb. Brightii.....	830.590	169.420	7.046	2.403	103.694	40.151	3.808	12.348
“ 20 “ “ “	826.891	173.109	3.060	1.860	109.432	41.300	4.377	13.280
“ 30 “ “ “	823.461	176.539	5.000	2.520	97.010	54.090	5.100	12.819
Female 20 years, in pregnancy.....	806.898	182.322	2.102	3.041	72.200	89.300	7.600	7.980
Menstrual fluid.....	785.000	208.170	—	2.580	76.540	109.650	10.750	8.600
Horse with glanders, from carotid.....	—	—	—	0.800	34.000	58.000	2.100	3.000
“ “ “ “ jugular v.....	—	—	—	1.000	37.500	56.200	2.300	4.000
“ “ “ “ vena port.....	—	—	—	1.200	35.000	57.800	2.500	4.500
Horse “ “ arterial blood	760.084	239.952	11.200	1.856	78.880	136.148	4.872	6.960
“ “ “ “ venous blood	757.351	242.649	11.350	2.290	85.875	128.698	5.176	9.160
Blood of a horse.....	808.809	191.194	9.011	4.820	103.740	54.600	4.360	14.650
Oxen in health	795.000	205.000	—	5.590	95.050	83.836	6.335	11.181
Calf	777.279	222.721	2.600	4.191	83.925	105.925	24.44	—
Cyprinus carpio.....	872.000	128.000	—	2.967	83.850	21.410	3.225	6.129
Cyprinus tinca	900.000	100.000	—	4.630	68.800	13.800	1.850	2.770
Bufo variabilis	848.200	151.800	—	9.607	112.330	21.860	7.893	2.429
Chyle of a horse.....	940.670	59.330	0.440	1.186	42.717	0.474	—	8.360

The colorless fluid, which forms the blood of the lower classes of animals, has not yet been sufficiently investigated. Blood of *earthworms* is transparent, of a reddish blue color, which, on exposure to air, becomes perfectly red, but in which no blood-globules are visible even by great magnifying power. According to the experiments of Hünefeld, it contains albumen and hematin, but no fibrin or globulin.

Blood in Diseases. The peculiar property of the blood in the beginning of inflammatory diseases, to coagulate in an unusual manner, forming on the top of the clot what is known as the inflammatory or buffy coat (*crusta inflammatoria*) has long been known to physicians. This is owing to a subsidence of the red particles before the coagulation of the fibrin commences, by which the upper part of the coagulum, which soon afterwards forms, becomes of a white or grayish yellow color, while the lower part is red as usual, from the enclosed red particles. Subsequently this upper portion contracts considerably more than the lower, which is kept extended by the enclosed blood-globules. The essential condition of the formation of the buffy coat is an increase in the quantity of fibrin (or its oxides) in proportion to the globules, by which the blood coagulates slower, and at the same time the blood-globules settle readier, while the fibrin remains in solution. It may be artificially imitated with healthy blood, especially of man or cats, by the addition of a certain quantity of such salts, which retard the coagulation, as, for instance, carbonate of potassa or sulphate of soda. According to the last investigations of Mulder, the buffy coat, when freed from the adherent albumen, contains no true fibrin, but consists mainly of two oxides of protein (oxyproteins), formed from the fibrin of the blood by oxidation, in consequence of the inflammation in much larger quantity than in the normal healthy state (see under FIBRIN and PROTEIN). The buffy coat contains, besides, from $2\frac{1}{2}$ to 3 per cent. of fat.

Andral and Gavarret have performed a number of analyses of blood with a view to determine the quantities and variations of its essential ingredients in different diseases, for which we refer to *Ann. de Chem. et de Phys.* lxxv. p. 225, and v. 404 (3d series). They estimate the following as the usual or normal quantities of each ingredient in 1000 pts. of healthy blood: fibrin 3, globules 127, solid matter of serum 80, water 790. The extreme variations of each ingredient noticed by them were fibrin from 0.90 to 10.0 in every 1000 parts of blood; the globules from 21 to 185; the solid parts of the serum from 57 to 104 and the water from 725 to 915. Abstinence from food and loss of blood by venesection, diminish the solid ingredients, but act more especially upon the globules. During acute inflammatory affections there is an invariable increase in the quantity of (oxidized) fibrin proportional to the intensity of the inflammation.

In Asiatic cholera the blood is deprived of a large amount of its water, with a small proportion of its solid ingredients, by the thin liquid evacuated during this disease by the intestinal canal, by which the blood is so much concen-

trated as to be impeded in its circulation, containing 25 to 52 per cent. of solid matter. It also seems to contain less alkali than in health. Lassaigne has proved that at least in some cases of jaundice the coloring matter of the bile is actually contained in the blood. (See under BILE.)

In suppression of urine, the blood is also found to contain urea. In a case of suppression of urine, in dropsy after scarlatina, both the blood and the serous effusions were found by one of the authors to contain urea to the amount of $1\frac{1}{2}$ grains to the ounce. The urea may in such cases be detected by precipitating the blood with strong alcohol, evaporating the alcoholic liquid in a water-bath to dryness or syrupy consistence; again, if necessary, dissolving in anhydrous alcohol and evaporating to dryness in a water-bath, and dissolving the residue in a small portion of water, by which fat remains, and after concentration of the filtered liquid, mixing it with cold nitric acid, by which crystals of nitrate of urea precipitate either immediately or after the lapse of some time. Urea has also been found in the blood of persons affected with Bright's disease of the kidneys, and with cholera.

In diabetes, in which the urine contains sugar, this substance has also been sought for in the blood, but mostly without success, except in one case by Ambrosiani. In many cases of this disease, the serum of the blood has been found combined with so much fatty matter as to resemble an emulsion. A similar condition of the blood has also been observed in affections of the liver.

Lecanu and Zanarelli have analyzed white blood from a person suffering from mania a potu. These examinations confirm the observation that the white color is owing to an excess of fatty matter. Fibrin is entirely wanting, and hematin has almost disappeared. The following is the result of their analyses:

	Zanarelli.	Lecanu.
Water.....	90.5	79.4
Albumen.....	7.6	6.4
Crystallized fat....	0.4	Fat..... 11.4
Oily fat.....	0.6	Hematin..... traces
Extractive and salts	0.5	Extract with } some fat.. } 2.5

Detection of blood-stains on Steel and Linen.

Blood-stains on Steel. When the blade of a knife is stained by blood, it is red when the layer is very thin, but brown if thicker: heated to about 80°, the blood-spot peels off, leaving the steel tolerably clean; no such appearance arises from common rust, but something like it may be produced by the juice of fruits; in that case the blood-spot may be distinguished from that of vegetable juices, by collecting the portion which scales off, and heating it in a glass tube closed at one end; it exhales the odor of animal matter and ammonia, and the latter may be recognised by its alkaline reaction on test-paper: any of the vegetable stains would, under such circumstances, exhale acid fumes; and mere rust would either give out nothing, or, at all events, the slightest possible trace of ammonia. Where it is practicable, the following process is more

exact; the stained steel is immersed in water; the hæmatin and albumen (uncoagul.) gradually dissolve, and leave the fibrin on the blade, from which it may be removed by the nail; red streaks form in the water, which becomes red at bottom: divide this red part into several portions; to 1 add chlorine; it becomes green, then colorless, and then deposits white flakes. To 2 add ammonia, which does not alter the color when from blood, but if from any ordinary dye-stuff, it becomes purple. Into 3 drop nitric acid; it becomes pale-gray. Into 4 a drop or two of infusion of galls; it does not alter the color, but occasions a slight cloud. Heat 5 till it boils, when it either deposits flakes, or becomes opalescent. Of these tests, nitric acid and infusion of galls are the most delicate; should rust of iron have mingled itself with the liquid, it may be separated by filtration.

Blood-stains on Linen, &c. Suspend the piece of linen in a little water; the fibrin remains upon it, and may be detected by the evolution of ammonia, if linen or cotton, on the application of a sufficient degree of heat, in a small tube; but the hæmatin and some albumen are dissolved or extracted; test the colored solution as above directed. Should the blood have coagulated upon one piece of linen, and then have gone through, so as to discolor another, no fibrin will be found on the latter. It is possible that a solution of madder, or some such coloring matter, in a serous or albuminous liquid, might lead to deception; but in this case the stain upon the linen would not be so easily removed by water, and the red solution would become yellow by acids, and violet by alkalis: a mixture of serum and the red of madder is rendered yellow, and does not remain red, on adding infusion of galls.

Uses. Ox-blood is used for several technical

purposes. It was formerly much employed by sugar-refiners for clarifying, its action depending upon its albuminous constituent. It is also largely employed in the manufacture of prussiate of potash, to which it is well adapted, from its large content of nitrogen.

BLOODSTONE. *Min.* See QUARTZ.

BLOWPIPE. *Min. Chem.* An instrument employed to obtain an intense heat, by forcing a current of atmospheric air through a common white flame of oil, tallow, &c., or by burning currents of mixed combustible gases and oxygen. We distinguish the mouth, table, and hydroxygen blowpipes.

MOUTH BLOWPIPE.

This little instrument is of the highest value to the chemist in qualitative analyses, in ascertaining the nature of substances present in any compound, or in confirming results obtained in the humid way; it is of equal value to the mineralogist in determining the nature and more or less of the composition of a mineral under examination. The blowpipe, with its few tests and few accompanying instruments, forms a small portable laboratory, with which a vast number of useful investigations can be carried on. We shall consider, 1st, the apparatus; 2d, the tests and their use; 3d, the results of experiments with the elements or their compounds, or their behavior.

1. Apparatus.

Blowpipe. By urging a blast of air horizontally through the flame of a candle or lamp (see FLAME), the white light disappears by a more rapid and intense ignition of the combustible matter, and is replaced by a blue cone of light with a faint outer rim of a yellowish or reddish hue. The mouth blowpipe is designed to produce this effect, and has received various

Fig. 32.

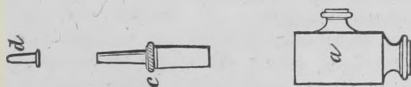
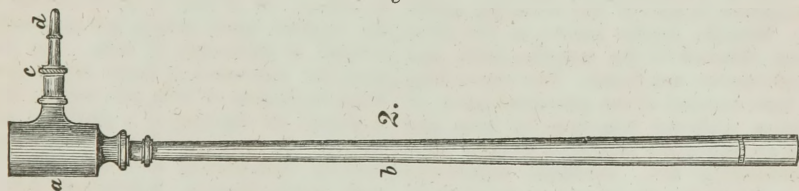


Fig. 33.

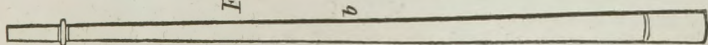
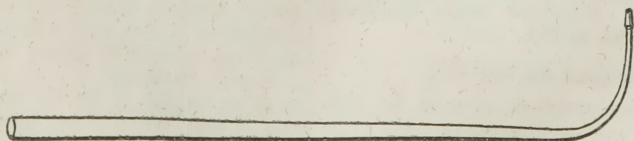


Fig. 33.



forms. It is always made of metal, brass, argentan, silver, or tin. Fig. 32, represents Gahn's blowpipe, which is one of the best, consisting of three parts: the hollow cylinder, *a*, in which the moisture of the breath condenses, the long hollow shaft, *b*, by which the blowpipe is held in the hand, with its upper end terminating in an ivory mouth-piece, and its lower fitting by its conical form in the solid cylinder, and the small tube, *c*, fitting in like manner into the cylinder. A small platinum cap, *d*, of a conical form, is fitted on the end of *c*, and is removable at pleasure, in order to burn off the carbon that adheres to it, and to cleanse the tube. The several parts of this blowpipe are represented separately; indicated by the same letters. The common mouth-blowpipe of the jeweller, fig. 33, a plain brass tube, tapering, and bent at right angles towards the point, will answer the same purpose, but after continued blowing, it is apt to become charged with moisture. The opening for producing the jet should be round and about the size of a small pin.

Flame. A wax or sperm candle, or small oil-lamp may be employed, the latter with a single, straight, elongated wick being preferable to the others. It were useless to give too minute directions for producing the flame, since the operator will be successful after a few persevering attempts. Grasp the mouth-piece with the lips, close them firmly, distend the cheeks slightly, and try to breathe through the nostrils while air escapes through the blowpipe. The flame should present an interior cone of a blue tint and an outer faint reddish tint free from white light. Within the outer rim of the blue cone, the combustible gases of the oil are in a state of imperfect combustion from a limited supply of oxygen. This part of the flame, the extreme end of the blue flame, is the hottest, and is called the *reducing* flame, from its intensity of heat, and its being an atmosphere in part of the reducing agent, carbon. Metallic oxides heated at this point are often reduced to the metallic state, and many substances are fused. The outer faint rim of light consists of the generated gases of combustion rendered luminous by heat, and receives an unlimited supply of oxygen from the surrounding air. Oxidable substances heated in this flame are placed in the most favorable situation for oxidation, viz. a high temperature and the free access of oxygen.

Supports. The substance under examination is usually placed upon charcoal, which often acts as a test (see below). It is sometimes held in a forceps with platinum points, especially if rather infusible. Or if it be treated with flux, it is placed on the end of a platinum wire bent into a crook at one end, or on thin platinum foil held at one end by the fingers or pincers. Glass tubes, open at both ends, or closed at one end, are employed chiefly for determining volatile substances. Their use is more minutely described under *Qualitative Analysis of Solids*, p. 174.

2. Reagents and their Uses.

The following excellent view of the principal reagents is from Fresenius:

1. *Charcoal.* Any kind of completely calcined wood-charcoal may be used for blowpipe experiments. The charcoal of smaller branches of pine or willow is preferable to any other sort. Smooth and rather compact pieces ought to be selected, as knotty pieces split and throw off fragments of the test specimen when heated.

It is principally used as a support, its value depending on the following properties: 1st, its infusibility; 2d, its low conducting power for heat, which admits of a substance being heated more strongly upon a charcoal than on any other support; 3d, its porosity, by means of which it imbibes easily fusible substances, such as borax, soda, &c., whilst infusible bodies remain on its surface; 4th, its property of reducing oxidized bodies, by means of which it co-operates in the reduction of oxides by the inner flame of the blowpipe.

2. *Carbonate of Soda.* For its purification, which is essential, see under *Sodium*. We employ this reagent, on account of its fusibility, to promote the *reduction* of oxidized substances by the inner flame of the blowpipe. In fusing, it brings the oxides into most intimate contact with the charcoal support, and allows the flame of the blowpipe to embrace every part of the specimen. But it does not co-operate in this process by its matter, or by decomposition. If the quantity operated upon is very minute, the reduced metal will often be found in the pores of the coal. In such cases, the parts surrounding the little hole which contained the sample, are taken off with a knife, triturated in a mortar, and the coal washed off from the metallic particles, which then become visible, either as powder or as small and flat spangles, according to their various nature. In many cases, e. g. in the reduction of peroxide of tin, it is advantageous to add some borax to the carbonate of soda, in order to render the mass more easily fusible.

In the second place, carbonate of soda serves as *solvent*. It is best to use platinum wire as the support, when testing whether bodies are soluble in carbonate of soda. For this purpose the substance is made into a paste with some carbonate of soda and water; this paste is placed on the loop of a platinum wire, and heated. A few only of the bases dissolve in melting carbonate of soda, but acids dissolve with facility therein. Silicic acid differs from all other acids, inasmuch as the glass which it forms with carbonate of soda remains clear on cooling, if, of course, the two constituents are present in the right proportion to each other.

Carbonate of soda is moreover applied as a means of *decomposing*, and rendering other bodies soluble, especially the insoluble sulphates, with which it exchanges acids, whilst, at the same time, a reduction of the new-formed sulphate of soda to sulphuret of sodium takes place; when fused together with sulphuret of arsenic, both are decomposed, giving rise to the formation of sulphuret of arsenic and sodium, and of arsenite or arseniate of soda, and thus converting it into such a form as to admit of its being reduced by means of hydrogen.

Finally, carbonate of soda is the most susceptible reagent, in the dry way, for the detection of manganese, since, when fused together

in the outer flame of the blowpipe, with a substance containing manganese, it produces a green, turbid button, owing to the formation of manganate of soda.

3. *Cyanide of Potassium.* For its preparation, see under **CYANOGEN**. This reagent is a powerful reducing agent in the dry way. It separates the radicals not only from oxygen combinations, but also from sulphur combinations, giving rise, in the first case, to the formation of cyanate of potash, by absorbing oxygen, and, in the latter case, to the formation of sulphocyanide of potassium. We may, by means of it, obtain pure metals from their combinations, as e. g. antimony from antimonious acid, or from sulphuret of antimony, iron from peroxide of iron, arsenic from arseniates, &c. &c. The separation of these metals is much promoted by the easy fusibility of cyanide of potassium. As a blowpipe reagent, cyanide of potassium is also highly useful; substances like peroxide of tin, sulphuret of tin, &c., &c., which, for their reduction with carbonate of soda, require rather a strong flame, are reduced with the greatest facility when cyanide of potassium is used. In blowpipe experiments we always use a mixture of equal parts of carbonate of soda and of cyanide of potassium, since the cyanide of potassium alone fuses too easily. This mixture, besides its more powerful action, has another advantage over carbonate of soda: it is with extreme facility imbibed by the porous charcoal, so that the purest metallic globules are obtained.

4. *Biborate of Soda.* (*Borax.*) Boracic acid shows a great affinity for oxides, when brought into contact with them whilst fusing. It combines, therefore, in the first place, directly with oxides. 2. It expels weaker acids from their salts; and, 3, with the co-operation of the outer flame of the blowpipe, it disposes metals, sulphur combinations, and haloid combinations to oxidize, in order to combine with the oxides. The borates produced, generally fuse readily by themselves, but by far more easily when fused together with borate of soda; the latter salt acts in this operation either as a mere flux, or by giving rise to the formation of double salts. In the biborate of soda, we have, 1, free boracic acid; and 2, borate of soda; and thus both conditions united, by which, as before stated, oxides, sulphurets, metals, &c., are disposed for solution and fusion; borax is therefore, as a blowpipe reagent, of the greatest importance in analytical chemistry. Charcoal, platinum wire, or foil are used as supports in this operation, heating the loop of the wire to redness, dipping it into the borax powder, and holding it in the outer flame, whereby a colorless pearl is obtained. This pearl is brought into contact with the test specimen, either when still hot, or after being moistened, and thus a small quantity of the latter attached to it; it is then again exposed, first, to the flame of a spirit-lamp, then to that of the blowpipe, observing the phenomena which appear. When heated on charcoal, a bead is fused, and the test added to it while hot. The following points ought to be examined with especial care: 1. Whether the

specimen dissolves transparent or not, and whether it retains this transparency on cooling, or not. 2. Whether it shows a distinct and definite color, which, in many cases, e. g. with cobalt, leads to an instantaneous and certain detection; and, 3. Whether the pearls show the same or a different relation in the outer and inner flame. Phenomena of the latter kind depend on the mutation from higher degrees of oxidation to lower, or even to the metallic state.

5. *Phosphate of Soda and Ammonia.* (*Microcosmic salt.*) For its preparation, see under **SODIUM**. When this salt is heated, the ammonia escapes, together with the water of crystallization. There remains consequently a compound, which, with regard to composition (free acid and fusible salt), very nearly approaches borax. The action of microcosmic salt is therefore quite analogous to that of biborate of soda. We prefer it, however, to borax in many cases as a solvent or flux, as the glasses which it forms with many substances are more beautifully and distinctly colored than those of borax. Platinum wire is equally used as a support when employing microcosmic salt as a flux; it ought, however, here to be remarked, that the loop of the wire must be small and narrow, or else the pearl will not stick to it. The operation is conducted as stated in the preceding paragraph.

6. *Nitrate of Cobalt.* For its preparation, see under **COBALT**. When heated with certain infusible substances this reagent forms with them combinations of divers various characteristic colors, and may therefore serve for the detection of those substances. Experiments of this kind are conducted in the following manner. The substance under examination, reduced to powder, is heated to redness on a charcoal support, the smallest possible drop of solution of nitrate of cobalt is then dropped upon it, and it is again heated to redness. In this process, oxide of zinc assumes an intensely green color, alumina a blue, and magnesia a feeble rose tint. The rose tint of magnesia is of so little intensity that beginners may easily overlook this reaction. Silica, also, when moistened with solution of nitrate of cobalt and heated to redness, assumes a feeble blue tint, which ought to be borne in mind when testing for alumina. The blue compound of the latter is, however, by far more beautifully and intensely colored than that of silica. (*Fresenius.*)

The following reagents are of limited utility. Vitrified boracic acid, to detect phosphoric acid by means of fine iron-wire. Bisulphate of potassa, for detecting lithia, boracic acid, and bromine. Metallic tin is useful to assist in reducing metallic oxides to metal or lower oxides. Pure lead and bone-ash are used for cupellation. Silica is employed to detect sulphur or sulphuric acid, oxide of copper for chlorine, strips of red and blue litmus paper for free acid.

3. Behavior of Oxides and Acids.

The following tables drawn from Parnell exhibit the reaction of the various metallic oxides, acids, and metalloids before the blowpipe, either alone or with various reagents.

Behavior of Alkalies and Earths.

	Alone.	Color of flame produced by moist soluble Salts.	With Borax.	With Microcosmic Salt.	With Carbonate of Soda on Charcoal.	Moistened with Solution of Nitrate of Cobalt.
POTASSA.	Fusible.	Faint reddish or violet.	The red glass of borax and nickel is changed to blue.			
SODA.	Fusible.	Intense greenish yellow (characteristic).	The red glass of borax and nickel is not changed to blue.			
LITHIA.	Fusible.	Crimson (characteristic).				
BARYTA.	Infusible. The hydrate and carbonate are fusible.	Pale apple green.	Colorless bead, opaque if saturated with baryta.	A colorless bead becomes opaque when cold, if saturated.	Is absorbed by the charcoal.	Brick or yellowish red while hot; colorless when cold.
STRONTIA.	Ditto.	Intense crimson (characteristic).	Ditto.	Ditto.	Not dissolved.	Black or gray.
LIME.	Infusible, gives a strong light.	Reddish purple.	Ditto.	Ditto.	Not dissolved; is absorbed by the charcoal.	Ditto.
MAGNESIA.	No change.		Ditto.	Ditto.	No action.	Flesh color after strong heating (characteristic).
ALUMINA.	Ditto.		Colorless glass, remains so when cold. Opaque with excess.	Transparent glass.	Undissolved.	A fine azure (characteristic).
GLUCINA and YTRIA.	Ditto.		Transparent glass; becomes milky by an intermittent flame.	As with borax.	No action.	Grayish black.
ZIRCONIA.	Infusible, gives a very powerful light.		Ditto.	Scarcely transparent.	Ditto.	

	Alone.		With Borax.		With Microcosmic Salt.		With Carbonate of Soda.
	Oxidating flame.	Reducing flame.	Oxidating flame.	Reducing flame.	Oxidating flame.	Reducing flame.	
ANTIMONY, Oxide of.	Sublimes; gives a greenish blue flame; is reduced on charcoal.		Yellow glass while hot; colorless when cold.	Gray from reduced metal.	Faint yellow glass; colorless when cold.	Gray from reduced metal.	Colorless glass on wire. Reduced on charcoal. The reduced metal is very fusible and brittle, disengages a white smoke of oxide when heated in the air.
BISMUTH, Oxide of.	Fusible; dark brown while hot, yellow when cold on wire. Reduced on charcoal.		Colorless bead.	Ditto.	Brownish yellow while hot; colorless when cold.	Reduced.	Reduced on charcoal. The reduced metal is brittle; heated on charcoal it gives a yellow coating of oxide.
CADMIUM, Oxide of.	On platinum wire, no change. Is reduced on charcoal and volatilized, giving an orange red coating of oxide.		Yellowish glass, colorless when cold; becomes opaque with an intermitting flame.		A transparent glass, opaque when cold, if saturated.		Does not melt on the wire. On charcoal it is reduced, and cadmium is volatilized. The charcoal acquires a reddish brown coating (characteristic).
CERIUM, Oxide of.	Protoxide becomes peroxide.		Red or orange when hot, pale when cold.	Colorless; milk white if saturated.	As with borax.	Colorless.	Not dissolved.
CHROME, Oxide of.	No change.		Red while hot, green when cold.	Green.			In oxidating flame, dark orange when hot, opaque when cold. In reducing flame, opaque; green on cooling.
COBALT, Oxide of.	Ditto.		Deep blue (characteristic).				Reduced on charcoal, giving a gray magnetic powder.
COLUMBIC ACID.	No change.		Colorless; becomes opaque when cold by an intermitting flame.			Colorless glass.	Combination with effervescence; no solution or reduction.
COPPER, Oxide of.	Bromide and chloride give a blue flame; most other salts give green.		Green while hot.	Brown red; increased by the addition of tin.		As with borax.	Green when hot; colorless and opaque when cold. Is reduced on charcoal, giving a red malleable metal.
IRON, Peroxide of.	No change.	Fuses. | Blackens and becomes magnetic.	Red while hot, pale when cold.	Bottle-green.		As with borax.	Reduced on charcoal, giving a magnetic powder.
LEAD, Oxide of.	Gives a clear blue flame. Fuses to a fine orange glass; is reduced on charcoal.		Yellow; nearly colorless when cold.			Green when hot, almost colorless when cold.	A transparent glass on wire, yellow and opaque when cold. Instantly reduced on charcoal.
MANGANESE, Oxide of.	Infusible. Protoxide becomes brown.		Amethyst, black if in excess; as-justed by nitre.	Colorless if quickly cooled.		As with borax (characteristic).	With soda on platinum-foil an opaque green (characteristic).

Behavior of Metallic Oxides.

	Alone.	With Borax.		With Microcosmic Salt.		
		Oxidating flame.	Reducing flame.	Oxidating flame.	Reducing flame.	
MOLYBDIC ACID.	Fuses, giving a smoke in the open inclined tube and on platinum foil. Is reduced with difficulty on charcoal.	Colorless on platinum wire.	Brownish red on charcoal.	Colorless on platinum wire.	Dark blue or black; green when cold.	With Carbonate of Soda. Is reduced on charcoal.
NICKEL, Oxide of.	No change.	Orange red; almost colorless when cold.	Gray from reduced metal.	Red; colorless when cold.	As in oxidating flame. Tin destroys the color.	Gives the reduced metal on charcoal. A magnetic powder.
SILVER, Oxide of.	Instantly reduced.	Partly reduced and partly dissolved.		Yellowish by daylight; red by candle-light. Opalescent in excess.	Gray.	Reduced.
TELLURIUM, Oxide of.	Gives the flame a green color. Fuses and sublimes; is easily reduced on charcoal.	Milk white or opaline when cold.	Gray.	Colorless.	Gray.	On the wire a colorless glass, which becomes opaque on cooling.
TIN, Oxide of.	In oxidating flame, protoxide becomes peroxide. In reducing flame is reduced by long heating.	Colorless.	Gray.	Colorless.	Colorless.	Easily reduced on charcoal, giving a soft and very fusible metal.
TITANIC ACID.	No change.	Colorless; becomes opaque on cooling.	First yellow, then amethyst; darker on cooling.	Colorless.	Yellow while hot; violet when cold.	Dissolves with effervescence, giving a yellowish glass, which becomes grayish white and opaque on cooling. Is not reduced on charcoal.
TUNGSTIC ACID.	Blackens, does not fuse.	Colorless.	Orange, becoming darker as it cools. Tin produces an enamel.	Very slightly yellow.	Very fine blue; oxide of iron makes it blood-red; this is prevented by tin.	Dark yellow glass; becomes opaque on cooling. Is reduced on charcoal.
URANIUM, Oxide of.	Ditto.	Yellow.	Green; blackened by an intermitting flame.	Yellowish while hot; greenish when cold.	Green.	Insoluble.
VANADIC ACID.	On charcoal, fuses, and is partially reduced.	Yellow.	Brown when hot; green when cold.	As with borax in both flames.		Dissolves.
ZINC, Oxide of.	Gives a strong whitish green flame. Slightly yellow while hot (by daylight); white when cold. Becomes green with solution of nit. of cobalt.	Transparent glass, becoming milky by an intermittent flame.	Reduced; the metal volatilizes.	As with borax in both flames.		Insoluble. Is reduced on charcoal, which becomes covered with a sublimate of oxide, which is yellow when hot, and whitens on cooling.

Acids and Metalloids.

Carbonates are best tested in the humid way by chlorohydric or nitric acid.

Hydrates are heated in a closed glass tube. The smallest amount of moisture condenses on the sides of the tube.

Sulphates. Mixed with the colorless and transparent glass of silica and soda, sulphates give, in the interior flame, a deep yellow or red color, either immediately or on cooling. Heated with soda on charcoal, in the interior flame, the resulting mass blackens metallic silver when moistened.

Nitrates. Those which are fusible deflagrate on charcoal. Infusible nitrates, heated to redness in a glass tube, give off nitrous vapors. All nitrates give deep red vapors when mixed with bisulphate of potassa and heated.

Borates. Fused with carbonate of potassa on charcoal, and moistened with sulphuric acid and alcohol, a green flame is produced. Mixed with a flux of one part of fluor spar and four and a half of bisulphate of potassa, borates give a dark green flame for an instant, when held at the point of the blue flame on a platinum wire.

Phosphates. To detect phosphoric acid, fuse the substance with boracic acid on charcoal; when fused, introduce the extremity of a steel wire and heat strongly in the interior flame. Borate and phosphuret of iron are formed; on breaking the fused mass (wrapped in paper) in a mortar, the phosphuret of iron is perceived, having the appearance of a metallic button, which affects the magnet, and is brittle.

Moistened with sulphuric acid, and held in the platinum tongs at the point of the blue flame, phosphates give a pale green color to the outer flame.

Silicic acid is characterized by dissolving easily in carbonate of soda with effervescence, giving a transparent and colorless bead. It is slowly dissolved in borax, giving a clear glass.

Seleniates and *selenites* give the characteristic odor of selenium, with soda on charcoal, in the interior flame. They behave like sulphates with the glass of silica and soda.

Arsenic. On charcoal, in the interior flame, the acids of arsenic give the characteristic alliaceous odor of arsenic. Mixed with black flux and heated in a glass tube closed at one end, a brilliant sublimate of metallic arsenic is formed, crystalline in its interior surface. It may be chased up the tube, becoming slowly oxidized. If the bottom of the tube be cut off, and the sublimed metal heated, it is immediately converted into arsenious acid, which condenses as a white crystalline sublimate. In a closed tube some arseniurets give a sublimed ring of shining metallic arsenic. In an open tube they sublime crystalline arsenious acid, and give an arsenical odor.

Sulphurets. Heated in an open inclined tube, or on charcoal, they evolve the odor of sulphurous acid, which acid bleaches moist Brazil-wood paper. Sulphurets behave as sulphates with the glass of silica and soda.

Seleniurets, in the exterior flame, evolve a strong odor resembling putrid horse-radish. Heated in the open tube, metallic selenium sometimes condenses. With the glass of silica

and soda, seleniurets behave as seleniates and sulphates.

Antimoniurets give a sublimate of oxide of antimony when roasted in the open tube.

Tellurets give, when roasted in the inclined open tube, a sublimate of a white powder, which, when heated, fuses into colorless drops before it sublimes.

Chlorides, added to a glass of microcosmic salt, saturated with oxide of copper (or held by a very small brass instead of a platinum wire), and suddenly heated, communicate a bright color to the flame.

Iodides, with the glass of microcosmic salt and oxide of copper, give a fine emerald-green flame. Heated with bisulphate of potassa in a glass tube closed at one end, iodine vapor is evolved.

Bromides, with the glass of microcosmic salt and oxide of copper, give a greenish blue flame. Heated with bisulphate of potassa, bromine vapor is expelled.

Fluorides. Those which contain water, give off hydrofluoric acid, when heated in a tube closed at one end. All fluorides, when mixed with bisulphate of potassa, or with microcosmic salt previously fused, and heated at the lower extremity of an open glass tube, evolve hydrofluoric acid, known by its corrosive action on glass, and its property of bleaching Brazil-wood test paper.

TABLE BLOWPIPE.

This very convenient, and to the chemist almost indispensable, apparatus, consists of a table, beneath which is a bellows worked by the foot, from which a current of air is forced through a tube terminating in a small orifice. This orifice is introduced a little way into the white or smoky flame of a large wick, some $\frac{1}{2}$ inch or more in diameter, and the current of air is forced a little upwards from a horizontal line. The fuel is either oil, tallow, or lard. By thrusting the orifice more or less into the flame, the blowpipe flame will be tapering to a point or spreading from the orifice into a cone, with a ragged base at its farthest point, producing in the latter case a peculiar noise. For heating a small surface, the former is preferable, for a more extended surface the latter. The pressure on the bellows may be regulated by weights which may be permanent, but they should be in some proportion to the orifice and size of the wick. A water-regulator is sometimes used to equalize the current of air, but it is cumbersome and unnecessary, and a small blacksmith's or organ-bellows produces a sufficiently uniform blast.

We employ a brass cylinder and piston, worked by a treadle, which drives the air into a large tin box immediately under the top of the table. From the front end of the box a tube rises through the table-top, and terminating with its small jet within the interior of an argand burner urges the air vertically upwards, producing flames similar to the above. The argand burner may be connected with a lamp or reservoir containing a solution of oil of turpentine in alcohol, or with a gas-pipe. In the former case the burner has a circular wick with a contrivance for adjusting its height

We employ the latter, which is neater, always ready, gives a powerful heat, and may be elevated or depressed at pleasure. Different jets with larger or smaller orifices may be employed. The convenience of this arrangement in the use of gas, an argand burner, and the solid metal piston, is such that we often substitute it for ordinary furnace operations.

The uses of the table blowpipe are manifold. Glass tubes are bent, blown out, &c., into a variety of small apparatus. Decompositions and ignitions are performed with great facility and rapidity. Substances may be fused which usually require a good wind-furnace. By driving the current of air obliquely and somewhat downward through the argand burner, the process of cupellation may be accurately performed on 20 grammes (300 grains) of lead.

HYDRO-OXYGEN OR COMPOUND BLOWPIPE.

The object of the instruments which have received this name is to enable us to employ, for the purposes of *fusion* or *illumination*, the intense heat of an ignited jet of the gaseous elements of water, hydrogen and oxygen.

To Dr. Robert Hare of Philadelphia belongs the credit of having first pointed out the greater heat, which ought to result from the combination of hydrogen with oxygen over all others, and to have invented the first apparatus for applying the flame produced by their union to the heating of substances.

In his first paper, in which he describes the apparatus invented by him for this purpose, he also gives an account of his experiments with it, having effected the fusion of a number of substances formerly considered infusible, and among other observations also notices the greater light emitted by them when subjected to this superior heat, although the hydro-oxygen flame, by itself, is rather destitute of illuminating power. (See *Memoir on the Supply and Application of the Blowpipe, &c.*, by Robert Hare, published by order of the Chemical Society of Philadelphia, 1802, and republished in *Tillich's Philosophical Magazine* for 1803, vol. xiv.) The appellation of *compound blowpipe* was given to it by Professor Silliman, it consisting, as it were, of two blowpipes connected into one.

In all compound, or hydro-oxygen blowpipes, therefore the gaseous elements of water form the material for the production of the heat, or, as it may also be expressed, the hydrogen is the fuel which is burned, and pure oxygen the gas which is used for supporting the combustion. These two gases have therefore to be prepared previously, and are then supplied from the blowpipe reservoirs just in the proportion in which they combine chemically, while another contrivance must be arranged where the gases issue, and are inflamed for the purposes of acting with safety and to the greatest advantage on the substances to be heated.

In regard to the manner in which the gases are kept in the reservoirs for supplying the jet, a great difference exists. In Dr. Hare's original apparatus, the two gases were kept in separate reservoirs, and only made to unite

near the orifice of their common efflux. When Humphry Davy subsequently discovered that the flame of explosive gaseous mixtures would not pass back through wire gauze or other small apertures, and thus a mixture of hydrogen and oxygen might be ignited at the point of their efflux without danger of communicating the fire to the explosive mixture in the reservoir, it was considered advantageous and more convenient to have the gases mixed beforehand in the proper proportions, and then to allow this mixture to pass out through small tubes, and to be inflamed at their apertures. The most common apparatus on this plan that has been used, is one contrived by Mr. Brooke, and executed by Newman, originally merely intended for the supply of a jet of oxygen. Fig. 1, Pl. vi. represents this apparatus as employed by Dr. Clark.

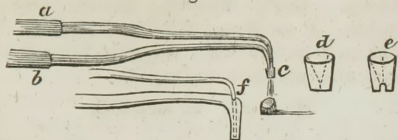
The gases are mixed in a bellglass and transferred into the bladder, C, and by means of the syringe, B, are condensed into the box, A, made of iron, from which they are allowed to escape through a fine thermometer tube, D, at the orifice of which they are ignited. For greater security, a safety cylinder is placed inside the box, A, which at the bottom is immersed in oil, and furnished at the top with fine wire-gauze, so that the condensed gases have to pass from the box through the oil and the gauze before reaching the stopcock and blowpipe nozzle. As a further precaution never to be omitted, a wooden screen is placed between the box and the operator. All such apparatus, however, is liable to disastrous accidents, for, notwithstanding these and other numerous contrivances invented to prevent the return of the flame, there is hardly any one which, from some unperceived or uncertain circumstance, will not fail at one time or another.

In all practical applications of the hydro-oxygen blowpipe this plan of employing the gases mixed beforehand in the reservoirs has been abandoned, and the original plan of Dr. Hare of discharging them from separate reservoirs again resorted to. The gases are generally kept in metallic reservoirs, and their regular and steady efflux effected by hydrostatic pressure and stopcocks, immersing the gasometers or reservoirs in water. For larger purposes closed reservoirs may in Philadelphia and other large cities, where such convenience offer, be connected by a pipe and stopcock with the pressure of the city waterworks. The hydrogen may in many cases be employed as obtained directly from a large self-regulating reservoir (see under *GASOMETER*) containing zinc and dilute sulphuric acid. The facility with which large india-rubber bags are now manufactured in the United States, and the convenience and nicety with which they are filled with the gases, and these retained, and subsequently discharged by superposed weights, has lately introduced them into extensive use for these purposes.

From the reservoirs the gases are delivered by pipes furnished with stopcocks to the orifices, where the combustion takes place. Near these the pipes are either made to combine by being united into one, as the two branches of

the letter, Y, or the pipe with oxygen terminates concentrically within the pipe discharging the hydrogen, likewise at, or a short distance inside its terminating orifice. The two different modes were already in the first instance employed by Dr. Hare, which may be seen from Fig. 34, taken from his original memoir of

Fig. 34.



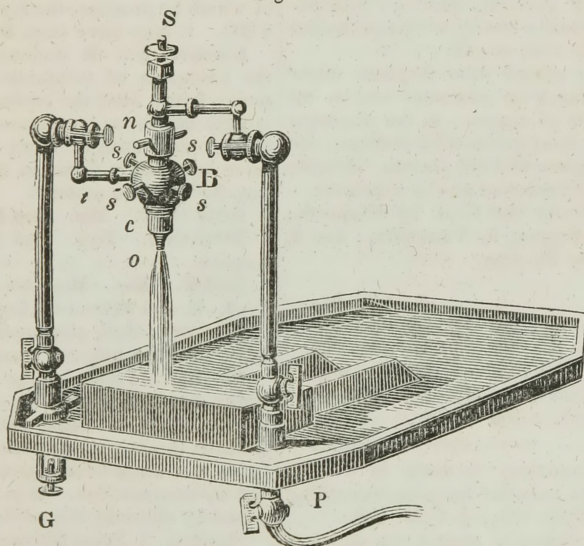
1802. *a* and *b* exhibiting the termination of the two delivery-pipes, being soldered into two perforations in the frustum, *c*, which converge till they form one, the open end of which is their common orifice, as seen by the dotted lines in *d*. *e* represents another frustum for the same purpose, where the two perforations terminate beside each other in a larger orifice or cavity. *f* represents the pipes as connected "when used for the fusion of platinum or subjects of the larger kind. They consist of a large and a small pipe, the orifice of the one

being inserted into that of the other, as may be understood from the dotted lines."

Just before the union of the two discharge-pipes these may be furnished with inserted safety-pipes, consisting of a number of short tubes with small bores, or containing a series of wire gauzes. The gases may also alter their mixture, before being discharged through the orifices, be conducted through a short pipe containing a similar safety-tube, but these safety-tubes are often dispensed with, as with proper precautions of always keeping the gases under sufficient pressure during the use, and attending the closure of the stopcocks, when not in use, no danger of retrogression and mixture of the gases, and consequent explosion, is to be apprehended.

Pl. VI., Fig. 2, shows a different form of the blowpipe, where the gases meet from the two sides in A, and are then emitted through B for ignition. The annexed wood-cut, fig. 35, exhibits another improved construction, where the two pipes terminate concentrically near their orifice, and the description of which may be found in the *Journal of the Franklin Institute*, vol. 1, 1826, p. 196, and in Dr. Hare's Compendium.

Fig. 35.



For the application of the compound blowpipe to purposes of light and illumination by the lime or *Drummond light*, which is produced by causing the hydro-oxygen flame to play on a cylinder of lime, the nozzle or orifice of the blowpipe must be pointed upward, in order to allow the flame to play on the lime (see under **DRUMMOND LIGHT**).

By exposing substances to the heat of the flame of the compound blowpipe, these are either applied in splinters held by forceps, or placed on supports of charcoal or fire-brick, having an excavation in which the substance is laid. In the latter case, the nozzle or orifice must always have a direction downward. In order to prevent the substance from being blown away, especially when in powder, it often becomes necessary to moisten it with

water and compress it in a mould. It is to the original inventor, Dr. Hare, that most of the subsequent improvements have been made, by which this apparatus has been employed for practical purposes; and under **PLATINUM** a description will be given of his last improved apparatus, which he employs for the fusion of large quantities of this metal for technical purposes.

Under the different substances, will be found an account of their behavior under the hydro-oxygen blowpipe where this requires special notice. Suffice it here to say, that the original experiments of Dr. Hare were afterwards repeated with additions and improvements by Professor Silliman, an account of which was published in the *Memoirs of the Connecticut Academy of Sciences* in 1813, and republished

BLUE IRON EARTH.

in Bruce's Mineralogical Journal. Since which time several others, mostly English experimenters, have occupied themselves with similar experiments, and that it may be said that scarcely any substance which could fairly be exposed to its influence has yet been found able to resist its liquefying power, and that by recent improvements Dr. Hare has increased the power of this instrument to such a degree as to fuse 28 ounces of platinum into one malleable mass.

BLUE IRON EARTH. *Min.* See **VIVIANITE**.

BLUE MALACHITE. *Min.* Syn. Blue Copper-ore, Blue Carbonate of Copper, Azurite; Prismatic Azure-Malachite, *Mohs*; *Ger.* Kupferlasur.

Descrip. Cryst. system, Oblique Rhombic. Main vertical prism M on M = $98^{\circ} 50'$, main plane P on M = $91^{\circ} 30'$. It often exhibits several lateral planes (the radical and other octahedra) and several in the same zone with P. Cleavage perfect parallel to M. It also occurs massive, imitative with fibrous structure; and earthy.

H. = 3.5 — 4.0. G. = 3.5 — 3.83.

Color various shades of azure-blue, sometimes very dark; lustre vitreous, shining; transparent; subtranslucent; brittle, with conchoidal fracture, and light blue streak.

Behavior. In a closed tube it gives water and blackens; fuses on charcoal and is reduced to a globule of copper; in the platinum pincers it gives a faint green color to flame; the fluxes give both green and red glasses. Soluble in acids with effervescence and in ammonia.

Analysis. 1. From the Ural, by Klaproth; 2, from Chessy, France, by Vauquelin; and 3, from the same, by Phillips.

	1.	2.	3.
CuO	70	68.5	69.08
CO ₂	24	25	25.46
HO	6	6.5	5.46
	100	100	100

Hence the empirical formula is 3 CuO, 2 CO₂, HO, or the rational formula, according to Berzelius, 2 (CuO, CO₂) + CuO, HO.

Localities, &c. Splendid specimens occur at Chessy, France; it also occurs at Moldawa in the Bannat; Huel Buller, Cornwall, &c. In America, near Puerto Principe, on Cuba, and on some of the smaller islands; in Nova Scotia on the Cariboo river; near Singsing, N. York; in several copper mines, New Jersey; near Nicholson's Gap, in the Blue ridge, at Perkio-

	1.	2.	3.	4.	5.	6.
Silica	42.00	41.05	41.9	42.00	45.922	47.036
Alumina	24.04	25.03	20.9	20.12	22.145	18.464
Peroxide of iron	10.03	8.09	12.2	8.53	trace	6.360
Magnesia	0.43	0.50	—	2.01	trace	trace
Lime	0.62	0.45	—	2.81	3.902	1.000
Potassa	—	—	—	0.50	—	Salt 0.900
Water	24.03	24.02	24.9	24.00	25.860	25.280
	101.05	99.14	99.9	99.97	97.829	99.040

BOLE.

men, Pennsylvania; fibrous, abundant in Warren county, Virginia.

BLUE SPAR. *Min.* See **LAZULITE**.

BLUE VITRIOL. *Tech.* See **Sulphate of COPPER**.

BLUE VITRIOL. *Min.* Tetarto-prismatic Vitriol-salt, *Mohs*; Sulphate of Copper; *Ger.* Kupfervitriol; *Fr.* Cyanose, *Beudant*.

Descrip. Cryst. system, Doubly Oblique Rhombic. P on M = $109^{\circ} 32'$; P on T = $127^{\circ} 40'$; M on T = $123^{\circ} 10'$. Cleaves imperfectly. Occurs also massive stalactitic.

H. = 2.5. G. = 2.213.

Color deep sky-blue, sometimes with greenish tint; lustre vitreous; translucent, subtransparent; taste metallic, nauseous; brittle, with conchoidal fracture and bluish white streak.

Behavior. Yields water in a closed tube, becoming white; readily reduced to copper on charcoal; soluble in water and in ammonia with a deep prussian-blue color.

Analysis. From Copiapo in Chili by H. Rose, according to whom its formula is CuO, SO₃ + 5 HO, which is the same as the artificial sulphate of copper.

Berthier analyzed a mixed silicate and sulphate of copper from Valparaiso, for the latter of which he proposes the formula 4 CuO, SO₃ + 4 HO. It may have been **BROCHANTITE**.

Localities, &c. It undoubtedly arises from the oxidation of sulphuret of copper, and is hence found near the surface in newly-opened copper mines, or in solution in waters issuing from older mines. Very beautiful crystals have been lately found in the copper mines of our N. Western states.

BOG ORE. *Min.* See **BROWN HEMATITE**.

BOILING. *Tech.* See **HEAT** and **VAPORIZATION**.

BOLE. *Min.* Massive, impalpable. H. = 1—2. G. = 1.977—1.6. Color yellowish or reddish brown; dull, glimmering; opaque; greasy, adheres to the tongue; streak shining, greasy.

Behavior. Yields water in a closed tube; burns hard and fuses on charcoal with intumescence to a dark yellow enamel; acts towards the fluxes like a silicate of iron. No. 5 fuses to a white vesicular enamel, without giving an iron-reaction. It is imperfectly decomposed by chlorohydric acid.

Analysis. 1. From Ettingshausen, and 2, from Cape de Prudelles by Löwig; 3, from the basaltic Säsebühl near Dransfeld by Wackenroder; 4, a variety from the broad mountain near Striegau; 5, a variety filling the clefts between the basaltic columns of Stolpen by Rammelsberg; 6, Erinite from Antrim, Ireland, by Thomson.

According to 1 and 2, it is a half silicate; from 3 Berzelius drew the formula of a $\frac{2}{3}$ silicate, which Rammelsberg's analysis, 5, confirms. Its formula is therefore $\text{Al}_2\text{O}_3, 2\text{SiO}_3 + 6\text{HO}$.

Thomson's Erinite, 6, approaches so nearly to 5 that it is probably the same. It is said, however, to burn white and not fuse before the blowpipe.

Uses. Bole appears to be disintegrated basalt. It was formerly introduced in medicine in small cakes impressed with a seal, whence its name *terra sigillata*. A chestnut brown variety from Sienna in Italy is employed as a pigment under the name of *Sienna* and *burned Sienna*. Bole is farther employed for pipe-bowls, in Turkey, Germany, by the North American Indians, &c. It is also used as a ground for gilding wood, &c.

BOLUS. *Min.* Similar to the preceding, Bole. *Analysis.* 1. From Sinope by Klaproth; 2, from Orawitz in the Bannat (Breithaupt's *Ochran*), and, 3, from Halsbrücke near Freiberg (Friesleben's *Fettbol*) by Kersten. The last is brown, becoming shining and greasy by friction.

	1.	2.	3.
SiO_3	32.0	31.3	46.40
Al_2O_3	26.5	43.0	3.01
Fe_2O_3	21.0	1.2	23.50
NaCl	1.5	—	—
HO	17.0	21.0	24.50
	98.0	96.5	97.41

These appear to be $\frac{1}{2}$ silicates, with a variable content of water.

BOLETIC ACID. Discovered by Braconnot in *Boletus Pseudoignarius*. *Prep.* Evaporate the expressed juice to a syrup, treat with alcohol, and wash the white undissolved residue with alcohol; dissolve it in water, precipitate with nitrate of lead, suspend this precipitate in water and decompose it by sulphuretted hydrogen. By evaporating the solution, the acid crystallizes, leaving a very acid mother liquor containing fungic and phosphoric acids; by resolution in alcohol and recrystallization, it is obtained purer.

Prop. Colorless, 4-sided prisms, of acid taste, like cream of tartar, reddens litmus, unalterable in the air, soluble in 180 pts. water at 68° , in 45 pts. alcohol. The greater part may be volatilized unchanged. It is characterized by precipitating the peroxide of iron perfectly and not the protoxide.

Salts. Boletate of potassa crystallizes with difficulty, is very soluble in water, insoluble in alcohol. B. of ammonia crystallizes readily in 4-sided prisms, unalterable in air, fusible, and sublimable. B. of baryta, crystallizes, tastes acid, difficultly soluble in water and nitric acid. B. of lime crystallizes in 4-sided prisms, soluble in 100 pts. cold water. B. of alumina and protoxide of manganese are insoluble. B. of protoxide of iron is soluble; the free acid dissolves iron with evolution of hydrogen, giving a yellowish solution, which soon becomes cloudy in the air. B. of peroxide of iron is precipitated both by the free acid and its salts, of a rust-red color; the peroxide is wholly precipitated. B. of lead is only soluble in an excess of acid.

B. of copper is difficultly soluble, and slowly precipitates in fine silky needles when formed by double decomposition. B. of silver soluble only in excess of acid.

BOLETUS. *Bot.* Various genera and species of mushroom are employed as food and for other purposes.

B. juglandis analyzed by Braconnot yielded:

Fat oil	0.03
Fat	0.10
Mushroom sugar	0.04
Nitrogenous substance insoluble in alco.	1.43
Nitrogenous substance soluble in alcohol	0.95
Vegetable albumen	0.58
Fungate of potassa with traces of phosphate of lime.....	0.48
Leathery skeleton.....	7.60
Water.....	88.77

B. laricis yielded to Bucholz:

Acrid resin, soluble only in boiling oil of terpentine.....	9.0
Resin very soluble in cold oil of terpentine	41.0
Bitter extract.....	3.0
Gum.....	6.0
Skeleton.....	30.6
Water and loss.....	10.4

The same B., analyzed by Bley, gave:

Gum with bitter extract and soluble salts of vegetable acids.....	8.30
Soluble vegetable albumen.....	0.70
Soft resin extracted by water with soluble substances.....	1.20
Resin extracted by boiling water, soluble in ether, not in essential oils.....	2.40
Resin then extracted by alcohol, soluble in ether and essential oils.....	23.50
Wax-like substance.....	0.20
Extractive matter.....	2.00
Boletic acid	0.13
Fungic acid.....	0.06
Tartaric and phosphoric acids.....	1.35
Potassa .33, lime .16.....	0.49
Coagulated albumen and a gummy substance extracted by muriatic acid	15.50
Resin then extracted by potassa	9.50
Fungin.....	15.00
Water.....	11.00

B. pseudoignarius is distinguished from other mushrooms by the uncrystallizable character of the sugar, which is more soluble in water than alcohol, and its solution is precipitated by barytic water, nitrate of lead, and tannic acid. It also contains boletates and fungates.

Uses. *Boletus (Polyporus) ignarius*, is cut in thin slices, and beaten with the hammer until soft, like buckskin, and impregnated with saltpetre, when it is used as tinder under the name of Spunk, Touchwood. *P. fomentarius* is used in a similar manner. The larch agaric (*Boletus* or *Polyporus laricis*) was formerly employed as a purgative medicine. *Polyporus Tuberaster* is much employed and esteemed as food in Naples and the Pontifical states. *P. annosus* is used in Sweden as an antidote to the bite of a snake.

BOLOGNIAN PHOSPHORUS. *Phys.* Heavy spar (sulphate of baryta) mixed with tragacanth paste to a stiff mass, dried, and ignited in charcoal, has the property of giving

off a yellowish light in the dark after exposure to the sun's light. It should be kept in well-stoppered bottles.

BOLOGNA VIAL, is a vial or tumbler of ordinary shape made of any kind of glass, much thicker at its bottom than in its upper portion, and which has not been annealed, but suddenly cooled in the air. From its thickness it will bear uninjured a considerable blow from any blunt instrument, as a wooden mallet, or the sudden concussion caused by the fall of a leaden bullet; but if any hard and angular substance, such as a small shiver of flint, or even a pointed grain of sand, be dropped into it, it will cause the bottle to break suddenly to pieces. This is caused by the extreme tension of the outer portion of the glass produced by the sudden cooling, which causes the particles to tear asunder like a stretched piece of cloth the moment the continuity of its surface is ruptured in any place.

BOLTONITE. *Min.* Massive, coarsely granular; cleaves in one direction more perfectly than in two others, which all indicate a doubly oblique rhombic prism. $H. = 5-6$. $G. = 2.8-2.9$. Color bluish or yellowish gray, yellowish white, the darker turning yellow on exposure; lustre vitreous, transparent, translucent; streak white. Before the blowpipe it becomes white without fusion. Thomson's analysis gives silica 56.64, alumina 6.07, protoxide of iron 2.46, magnesia 36.52 = 101.69. Berzelius supposes it to be $\frac{1}{2}$ silicate with binaluminate of magnesia and protoxide of iron. Kobell proposes $3 MgO, 2 SiO_3$, or a $\frac{1}{2}$ silicate of magnesia. *Localities.* It occurs disseminated through the white limestone at Bolton, Boxborough, and Littleton, Massachusetts; in dolomite at Ridgefield in bluish grains, and at Hill's quarry, Reading, Connecticut, of a pale straw-yellow color. (*Dana*.)

BONE. The different parts of the skeleton, or that solid framework which supports or protects the soft parts of the body of the higher orders of animals, are called bones; and owe their solidity to inorganic earthy materials which they contain. Bones are not equally compact throughout their whole substance, but exhibit on their surfaces an osseous mass of a denser nature, while their interior part forms a more or less cellular or spongy mass. The bones are covered both externally and internally by a membrane called periosteum, by which the ramifications of the blood-vessels and the nerves pass into them. This membrane is formed by a dense tissue which, by boiling with water, is converted into gelatin or glue. The long or cylindrical bones, such as those of the extremities, are hollow, and generally filled with marrow (refer to this article).

The bones themselves consist of a living or organic portion, formed of cartilage; and an earthy or inorganic, formed mainly of phosphate of lime, with a certain portion of carbonate of lime. The cartilaginous portion of bone is formed before the deposition of the earthy takes place, and the ossification always starts from certain fixed points called points of ossification. The mode of combination of the organic with the earthy matter is not well understood, but it is generally supposed to

exist by the extremely small cavities of the former, receiving earthy particles in the same way that a sponge holds water. (*Horner*.)

The organic or cartilaginous portion of the bones may be obtained in a separate state by immersion of a bone in diluted muriatic acid at a temperature of 54° or less. The acid dissolves the earthy portion without attacking perceptibly the cartilaginous, which is then freed from remaining acid by repeated steepings in cold water, and remains in the original form of the bone, but transparent, flexible, and elastic. By drying, it shrivels up, and becomes hard and brittle, but remains translucent. It is entirely converted into gelatin by boiling in water, with the exception of a few fibres, derived from the fine blood-vessels, which remain insoluble and may be separated by filtration. If bones be treated by heat with dilute hydrochloric acid, a portion of the cartilage is dissolved and a disengagement of carbonic acid is apparent, by which the bone, when half dissolved, begins to separate into fibrous longitudinal laminas, having the power, like mica, to polarize light.

The earthy or inorganic portion of bone consists mainly of phosphate and carbonate of lime in different relative proportions in different tribes of animals, and mixed with small and variable portions of phosphate of magnesia and fluoride of calcium.

The earthy portion of bone or bone-ash is easiest obtained by calcination of bones, but it then contains substances which do not exist in them originally, such as sulphate of soda, formed from the sulphur in the cartilage, and also alkaline carbonates from the same source. The carbonate of lime of the bone loses also in this way most of its carbonic acid.

The carbonic acid is combined in bones with the lime in the same proportion as in common carbonate of lime. The phosphoric acid, on the contrary, is combined with an excess of lime, forming a basic phosphate of lime of peculiar composition, $8 CaO + 3 PO_5$ (see *phosphate of lime* under **CALCIUM**), which is always obtained by precipitation of phosphate of lime by ammonia in excess.

The existence of *Fluoride of Calcium* in the bones may be proved by distillation of calcined bones with sulphuric acid. If the distillation be performed in a glass apparatus, the condensed distillate attacks the polish of the glass and contains fluosilicic acid in solution. The content of fluoride of calcium is less than 2 per cent.

The magnesia may be separated by dissolving calcined bone in nitric acid, adding ammonia till a precipitate begins to form, and then precipitating the phosphoric acid by acetate of lead. The filtered solution is freed from lead by sulphuretted hydrogen, saturated by ammonia, the lime precipitated by oxalate of ammonia, and the filtered solution evaporated to dryness, and the mass ignited, after which the magnesia remains pure. Sometimes it contains minute traces of oxides of iron and manganese. The composition of bone freed from periosteum and fat, and dried by heat till they lose no more in weight, will be seen from the following table.

BONE.

BONE.

	Berzelius.		Marchand.
	Bone of man.	Bone of oxen	Os femoris of man.
Cartilage	32.17	33.30	Sol. in mur. acid..... 27.23
Vessels.....	1.13		Insol. in mur. acid..... 5.02
Basic phosphate of lime, with a small } quantity of fluoride of calcium..... }	53.04	57.35	Basic phos. lime..... 52.26
Carbonate of lime	11.30	3.85	Fluoride of calc..... 1.00
Phosphate of magnesia	1.16	2.05	 10.21
Soda with a little chloride of sodium... 1.20		3.45	 1.05
			Soda..... 0.92
			Chloride of sodium..... 0.25
			Oxides of iron and mang.. 1.05
	100.00	100.00	100.00

The magnesia is obtained in the analysis as phosphate, but exists probably in bone as carbonate. The main difference between bone of man and oxen, it will be seen, consists in the former containing three times as much carbonate of lime as the latter, which, in the same proportion, contains more phosphate.

Rees has determined the proportion of or-

ganic and inorganic matter in different bones of man. The amount of organic matter through all his experiments is higher than obtained by Berzelius and Marchand. This may be owing to imperfection in desiccating, or in saturating the lime, subsequent to the calcination, with carbonic acid by digestion with carbonate of ammonia.

	Adult.		c. Stillborn infant.	
	a. Compact substance.			
	Organic.	Inorganic.	Inorganic.	Organic.
Femur.....	62.49	37.51	57.51	42.49
Tibia.....	60.01	39.99	56.52	43.48
Fibula.....	60.02	39.98	56.00	44.00
Humerus.....	63.02	36.98	58.08	41.92
Ulna.....	60.50	39.50	57.59	42.41
Radius.....	60.51	39.49	56.50	43.50
Os temporum.....	63.50	36.50	55.90	54.10
Vertebrae.....	57.42	42.58	—	—
Costa.....	57.49	42.51	53.75	46.25
Clavicula.....	57.52	42.48	56.75	43.25
Os Ilium.....	58.79	41.21	58.50	41.50
Scapula.....	54.51	45.49	56.60	43.40
Sternum.....	56.00	44.00	—	—
Os metarsi pollicis pedis.....	56.53	43.47	—	—
	b. Cellular substance.			
Of caput femoris.....	60.81	39.19		
Of a rib.....	53.12	46.88		

In *a* only the compact portion was employed, avoiding the cellular substance. It seems from this that the cylindrical bones of the extremities contain more bone-earth than the bones of the trunk, and those of the arm and thigh more than those of the forearm and the leg; from *b* it will be seen that the cellular structure contains less inorganic matter than the compact. In new-born infants, *c*, the different bones also vary in composition, but less than in adults. The bones of the trunk in *a* and *c* show nearly the same composition. The following are the results of Sebastian's, Frerich's, and others' analyses on the same points:

	Sebastian.		Frerich.	
	Inorganic m.	Organic m.	Inorg. m.	Org. m.
Cranium	60.00	40.00	Os parietale, adult.....	68.5 31.5
Humerus, femur and tibia... 63.34	36.66		“ “ 3 year child....	66.3 33.7
Cellular subst. of caput tibia 66.66	33.34		Pars petrosa oss. temp., adult.	68.0 32.0
			Maxilla inferior, 3 year child..	62.8 37.2
			Sternum, adult.....	64.7 35.3
			Costa “	65.3 34.7
			Humerus “	68.3 31.7
			Humerus and ulna, 8 months	
			fœtus.....	63.2 36.8
			Radius, adult.....	66.3 33.7
			“ boy 10 years.....	65.5 34.5
			Tibia, adult.....	66.2 33.8
			Fibula, “	66.5 33.5
			Carious excrescence of fibula.	61.2 38.8
			Os metatarsi, adult.....	65.9 34.1
			Patella	63.7 36.3
			Corpus vert. lumb., adult.....	60.5 39.5

	Frerich.		Compact bones.	
	Spongy bones.			
	1.	2.	1.	2.
Organic matter.....	38.22	7.42	31.46	30.94
Earthy phosphates.....	50.24	51.38	58.70	59.50
Carbonate of lime.....	11.70	10.89	10.08	9.46

BONE.

BONE.

	Schreyer.			H. Davy.	
	Child.	Adult.	Aged.	Child.	Adult.
Animal matter.....	47.20	20.18	12.2	53	12.2
Earthy "	48.48	74.84	84.1	47	48.1
	95.68	95.02	96.3	100	99.5

ANALYSIS OF BONES IN DISEASES.

1. In Osteomalacy.

	Bostock.		Proesch.		Bogner.			
	Vertebr. dors.	Vert. dors.	Costa.	Cranium.	Radius.	Femur.	Patella.	
Cartilage.....	79.75	74.64	49.77	65.85	63.42	69.77	70.60	
Phosphate of lime.....	13.60	13.25	33.60	26.92	28.11	23.50	23.23	
Phosphate of magnesia	0.82	—	—	0.98	1.07	0.97	0.94	
Carbonate of lime.....	1.13	5.95	4.60	5.40	6.35	5.07	5.03	
Sulphates of lime and soda...	4.70	0.90	0.40	—	—	—	—	
Fat.....	—	5.26	11.63	—	—	—	—	
Soda, oxide of iron, and mang.	—	—	—	0.85	1.05	0.69	0.64	
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	

	Marchand.			
	Vert. dors.	Radius.	Femur.	Sternum.
Cartilage.....	75.22	71.26	72.20	61.20
Fat	6.12	7.50	7.20	9.34
Phosphate of lime.....	12.56	15.11	14.78	21.35
Phosphate of magnesia.....	0.92	0.78	0.80	0.72
Carbonate of lime.....	3.20	3.15	3.00	3.70
Sulphates of lime and soda.....	0.98	1.00	1.02	1.68
Fluoride of calc., chlor. sodium, oxide of } iron and loss..... }	1.00	1.20	1.60	2.01
	100.00	100.00	100.00	100.00

2. In Arthritis.

	Thigh-bone.	Forearm.
Animal matter.....	46.82	45.96
Phosphate of lime.....	42.12	43.18
Carbonate of lime.....	8.24	8.50
Phosphate of magnesia...	1.01	0.99
Fluoride of calcium, soda, Chlor. sodium, and loss.	2.31	1.37
	100.00	100.00

3. Concretions on the femur of a child with rachitis.

	Marchand.
Urate of soda	34.20
Urate of lime.....	2.12
Carb. ammonia.....	7.86
Chloride of sodium.....	14.12
Water	6.80
Animal matter.....	32.53
Loss	2.37
	100.00

BONES OF ANIMALS.

Barras has determined the quantities of phosphate and carbonate of lime in the bone-earth of different animals in 100 parts.

	Phos. of lime.	Carb. lime.	Carb. lime to 100 of phosph.
Lion	95.0	2.5	2.03
Sheep	80.0	19.3	4.12
Chicken	88.9	10.4	1.70
Frog.....	95.2	2.4	5.76
Fishes.....	91.9	5.3	2.52

The bones of *fishes* contain less bone-earth in proportion to their amount of organic matter, and are generally more flexible.

	Chevreul.	Dumenil.	Marchand.	
	Cranium of cod.	Bones of pike.	Dors. vert of squalus cornubicus.	Cranium of a big ray.
Animal matter	43.94	37.36	57.07	78.46
Phosphate of lime.....	47.96	55.26	32.46	14.20
Sulphate of lime.....	—	—	1.87	0.83
Carbonate of lime.....	5.50	6.16	2.57	2.61
Phosphate of magnesia	2.00	—	1.03	—
Sulphate of soda	—	—	0.80	0.70
Soda with chloride of sodium	0.60	1.22	3.00	Cl ₂ Na 2.46
Fluor. calc., silica, alumina, oxide of } iron, and loss..... }	—	—	1.20	—
Fluor. calc. phos. of magnesia and loss	—	—	—	0.74
	100.00	100.00	100.00	100.00

In cartilaginous fishes (*pisces cartilaginei*) the skeleton consists of a peculiar animal matter, with no distinct bone-earth. The only chemical examination of this substance is by Chevreul, who examined the bones of *Squalus perigrinus* (Blainsville). This substance is translucent, of a bluish color, flexible, very sectile, and may be cut into thin slices. In its chemical behavior it resembles mucus more than any other substance. In warm water it swells up, becomes transparent and invisible, but it requires more than 1000 parts of boiling water for solution. The solution is not precipitated by an infusion of galls, and yields no jelly by evaporation. By long continued boiling, it is converted into a strongly gluing liquid, which does not gelatinize on cooling, but which is precipitated by a solution of tannin. In alcohol this substance shrivels up, while an oily fat is extracted. It is easily dissolved in acids, especially in chlorohydric, and the solution is coagulated by tannin. It would be interesting to know whether this substance do not form the cartilaginous portion of the bones of fishes properly so called.

Use. Bones are of extensive use in the arts. In their natural state, or dyed of various colors, they are made into handles and numerous articles of turnery. Under AMMONIUM has been mentioned the employment of bones for the manufacture of sal-ammoniac and volatile alkali, while the residuary portion of the bones from the distillation is used for the manufacture of prussian blue, or as bone-black, or by calcination to make bone-ashes (see the following articles). Calcined bones are also employed for the manufacture of phosphorus. By boiling in water, a fat may be extracted from fresh bones, and by Papin's digester their cartilaginous portion converted into a jelly, which, however, has not been found to answer the purpose of a wholesome sustenance. Bone-dust or ground bones are employed as a superior MANURE. The cartilaginous portion of bones is sometimes used for the manufacture of glue. See GELATIN.

BONE-ASH. Syn. Calcined bones; Burnt hartshorn. *Ger.* Knocheasche. Obtained by the calcination of bones, by which all organic matters are destroyed and their carbonate of lime converted more or less into caustic lime by losing all or part of its carbonic acid. The bones lose thereby about 63 per cent., and become soft, friable, and earthy, but retain their shape. Bone ashes consist mainly of basic phosphate of lime ($8 \text{CaO} + 3 \text{PO}_5$) with a certain amount of lime, and small quantities of fluoride of calcium, phosphate of magnesia, carbonate and sulphate of soda. Bone ashes from human bone contain 86.4 per cent., from cattle 90.7 per cent. phosphate of lime. It is sometimes purified by solution in chlorohydric acid and precipitation by ammonia, after which it only contains phosphate of lime, with a minute portion of phosphate of magnesia.

Calcined bones form, when ground or pulverized, a grayish white, almost tasteless, powder. It is used for making cupels for the cupellation of silver, and, when finely levigated, for cleaning articles of paste, trinkets, &c., under the name of burnt hartshorn. It is

also employed for the manufacture of phosphorus.

BONE-BLACK. Syn. Animal charcoal; *Fr.* Noir d'os, Charbon animal; *Ger.* Knochenkohle, Thierkohle. The black carbonaceous residue obtained by the dry distillation of bones, or by charring them by ignition in close vessels. This kind of animal charcoal is mainly used to deprive various solutions, as syrups, &c., of their coloring matters. Another less extensive use is as a black pigment. When prepared for this latter purpose, it generally receives the name of *ivory-black*, under which name pulverized bone-black is often sold in the shops (see IVORY-BLACK).

The antiputrescent and decolorizing properties of charcoal in general was first noticed by Lowitz. His observations were confirmed and followed up by Kels (1798) and Scaub (1800). The first useful application of charcoal from wood to the purification of syrups was made by Guillon. In 1811, Figuier of Montpellier showed that animal charcoal surpassed greatly vegetable charcoal in its decolorizing power, and in 1812 it was employed by Derosnes for the purification of syrups, and sugar-refining.

The manufacture of bone-black is performed by two different systems of apparatus. If the object be to condense and collect at the same time the volatile products which escape in charring bones, this process is formed in retorts similar to those employed for the distillation of coal in gas-works (see GAS and SAL-AMMONIAC under AMMONIUM). When the operation is finished, the bones are raked out while hot into receivers, which are covered air-tight till they are cool, and the retorts are immediately charged again with fresh bones.

Where the object is merely the manufacture of bone-black, the charring is performed in cast-iron pots or cylinders of the form as represented in Pl. VI., Fig. 3, D, which are piled one on top of the other, the bottom of the upper one forming the cover of the next beneath it, the joints being luted with clay, and the uppermost pot being closed by a cover, C B. The furnace in which these pots are heated resembles a potter's kiln, and may either be upright or horizontal. The former is represented in Pl. VI., Fig. 4, 5, and 6. A is the fire-place or grate for the fuel; cc are the openings in the vault of the fire-place through which the flame passes into the room, D, Fig. 5, where the pots are distributed. The arrangement of these openings is shown in c, Fig. 6. B (see Fig. 4) is the front wall, and E the door through which the pots are carried in, and which is afterwards built up with fire-bricks and clay. FF, fig. 5, are the lateral flues for conveying the smoke and disengaged gases into the chimney.

Fig. 7 and 8, Pl. VI., represent a horizontal kiln, fig. 7 being a longitudinal section, and fig. 8 the ground plan; a is the fire-chamber, lying upon a level with the sole of the kiln, and separated from the room c, where the pots are placed by the wall b, furnished with several rows of holes, dd, at different heights. e is the door through which the pots are carried in; ff the outlet holes for the gases and the smoke into the chimney g; h is a sliding damper plate

for regulating the admission of the air into the fire-space, *a*.

By this arrangement the offensive gases are partly consumed and partly carried off with the smoke. To destroy the smell completely, the smoke must be made to pass through the fire-place of a second small furnace with strong draft, erected for this purpose and fired with dry wood. The pots contain generally from 20—25 lbs. of bone. The number of pots that may be put into a kiln depends of course on its dimensions. From 20—37 cwt. of bones may be burnt at once.

After the dried and broken bones are filled into the pots, and these placed in the kiln and the door shut, the firing must at first be moderate, but afterwards raised and maintained at a brisk heat for 5 to 8 hours. The door of the ashpit and the damper may now be nearly closed to moderate the draught and keep up a steady ignition for 8 to 10 hours longer without additional firing, after which the doors must be all opened to cool the furnace. When this is done, the brickwork of the entrance door must be taken down, the kiln emptied and immediately filled again with a set of pots with fresh bones. The pots which have been ignited may in the course of a short time be opened, and the contents put into the magazine. Before being ground, they must be assorted in order to remove those pieces which have been burned white.

The bones lose, on the average, from 40 to 50 per cent. In reference to the quality as a decolorizing agent, experience has shown that it is so much more powerful as the bones from which it has been made were previously freed from adhering fatty, fleshy, and tendinous matters.

Before being put into commerce as bone-black, the ignited bones are broken up into a coarse powder by being passed between two iron cylinders and sifted through two sieves, one to remove the small dust, and one with large meshes to separate the proper sized grains from the coarser lumps. Sometimes it is ground to fine powder in a mill. The following is the average composition of common bone-black. (*Dumas*.)

Phosphate and carbonate of lime.....	88
Charcoal (nitrogenous)	10
Carburet or siliciuret of iron	2
Sulphuret of calcium or iron.....	trace

100

Purification of Bone-black. Bone-black necessarily contains phosphate and carbonate of lime; the presence of which does no harm in some decolorizing operations, but in many delicate chemical processes, such as the preparations of organic acids, alkalies, and many of their salts, they would be dissolved and decomposed, and thus be a source of impurity. It is for these reasons that bone-black requires to be purified from the calcareous salts which it contains, and this is effectually done by dilute muriatic acid, which dissolves them. For every pound of bone-black 10 to 12 fluid ounces of chlorohydric acid may be used di-

luted with an equal volume of water, in which the bone-black is digested at a gentle heat for two days, frequently stirring the mixture. The acid is then poured off and the bone-black washed with pure water as long as any acid is taken up, and subsequently dried.

Mode of using Bone-black. In general, it is only necessary for the decoloration of solutions to allow them to pass at ordinary temperatures through a stratum of bone-black sufficiently thick for this purpose, which may be conveniently performed in a *DISPLACEMENT*-apparatus. As the action is more rapid when hot than in the cold, it is usual in common chemical operations to raise the temperature of the solution which is to be decolorized to boiling. The bone-black is then thrown in, and the whole agitated for a short time and thrown on a filter. The liquid then passes through colorless. In some cases care must be taken not to boil the liquid too long while in contact with the bone-black, as portions of the coloring matter may again be taken up.

Decolorizing properties of Bone-black. All finely divided charcoals possess more or less the property of taking up from watery solutions a number of coloring substances, while this property is much less marked with regard to alcoholic solutions. This decolorizing power is, however, very different in different varieties of coals; animal charcoal possess it in a much higher degree than vegetable. The cause of this difference was for a long time unknown, until elucidated by the essays of Bussy and Payen, of which the former obtained the first and Payen the second prize of the Society of Pharmacy in Paris. The following may be considered as the main results of their investigations:

1. The charcoal acts on the coloring and other matters by combining chemically with them without decomposition.
2. That the decolorizing power of charcoal depends, in general, upon its state of division, or the extent of its surface.
3. This state of division cannot be obtained in any high degree by mere pulverization, but only by mixing animal or vegetable substances with inorganic substances, which may separate their particles, and by the subsequent heat or charring prevent the particles of carbon from uniting, by keeping them separated, so as to remain in a finely divided state.
4. Of all substances which may be employed for this purpose potash is most effective, but many other earthy and inorganic substances produce more or less the same effect.
5. Soft animal substances, which fuse by their charring, yield by themselves, without previous mixture with such substances, a very ineffective charcoal, on account of their fusion and the consequent coalescence of the carbonaceous particles.
6. Wood and other similar vegetable substances, which do not fuse by charring, yield a much more effective coal; still vitrification of the surface cannot be altogether prevented.
7. In charring bones, the carbonaceous particles remain in the highest degree of division from the earthy ingredients, the phosphate and carbonate of lime which they contain, hence their superior efficacy, in their decolorizing power, which is only due to

BONE-BLACK.

their carbonaceous matter. 8. The decolorizing power, from the above reasons, is, in most cases, proportional to their lustre, without regard to the source from whence derived; those which have a brilliant lustre being compact, and showing little or no decolorizing

BONE-BLACK.

power; those of a dull appearance being efficient.

The two last columns of the following table, taken from Bussy, exhibit the decolorizing power of charcoals obtained in different ways, compared with ordinary bone-black as unity.

Kind of charcoal.	Weight of charcoal employed.	Indigo test consumed.	Molasses test consumed.	Decolorizing power by indigo.	Decolorizing power by molasses.
	Gramme.	Litres.			
Crude bone-black	1	0.032	0.009	.1	1
Bone-black treated with muriatic acid.....	1	0.06	0.015	1.87	1.6
Oil ignited with phosphate of lime.....	1	0.064	0.017	.2	1.9
Lamp-black, not ignited	1	0.128	0.03	.4	3.3
“ “ ignited with carbonate of potassa.....	1	0.55	0.09	15.2	10.6
Charcoal from acetate of potassa.....	1	0.18	0.04	5.6	4.4
Blood ignited with phosphate of lime	1	0.38	0.09	12	10
“ “ “ chalk.....	1	0.57	0.10	18	11
“ “ “ carbonate of potassa.....	1	1.60	0.18	50	20
Albumen ignited with carbonate of potassa.....	1	1.08	0.14	34	15.5
Glue “ “ “	1	1.15	0.14	36	15.5
Bone charcoal formed by depriving bone of its phosphate of lime by an acid and ignition with potassa.	1	1.45	0.18	45	20

Restoration of Bone-black. Since the use of bone-black, more especially in sugar-refining, has become so extensive, that it becomes difficult to supply the demand, it has become a matter of importance to restore its original decolorizing power after it has been lost by use. The coloring and other organic matters which bone-black takes up form on its surface a layer, which prevents its further action, and which must be removed or destroyed in order to give it its former efficacy. To attain this object, various methods have been employed, such as heat, treatment with acids or alkalies, fermentation, &c. The first method resorted to was to ignite them over again in apparatus similar to those employed from the first for its manufacture; but in this case a product is obtained which does not equal the original, because the organic matter fuses by its charring, and forms a layer of compact shining charcoal on the surface of the bone-black.

Derosne's method consists in burning the organic matter taken up by calcination in free air. The bone-black is washed thoroughly with water, dried, and subsequently subjected to a kind of roasting on red-hot iron plates.

Peyron's plan consists in washing the bone-black with hot water, and without removing it from the filter-cylinders, allowing the organic matter in it to pass into putrid fermentation at an elevated temperature, and then removing it by renewed washings with water, after which it has recovered its former efficacy. This process may be repeated from 20 to 30 times without the necessity of adding fresh bone-black; but, although practicable in refineries of cane-sugar, it has been found accompanied by difficulties in regard to beet-sugar. Among other advantages it has that of not requiring the removal of the bone-black from the filtering apparatus; but, on the other hand, it is difficult to determine when the fermentation is sufficiently

completed for the restoration of the bone-black.

Another method is that of Danjeois, to inject into the filtering cylinders, in which the bone-black is contained, vapor heated to 750°, by which the precipitated organic matter is completely destroyed. The steam is heated by traversing an apparatus in which the necessary heat may be imparted to it, after which it is directly injected into the bone-black. The organic substances suffer hereby a kind of pyrogenous decomposition, the progress and termination of which is indicated by the smell.

Notwithstanding the various methods which have been proposed and in some instances successfully carried out for the restoration of bone-black, the original process of restoring it by ignition in close vessels, either alone or by the addition of fresh bones, is still resorted to, and more generally preferred, partly because it occupies less time in revivifying the black.

Testing of Bone-black. The amount of charcoal in bone-black may be ascertained by boiling it in a pulverized state for a quarter of an hour with an equal weight of nitric acid diluted with 3 parts of water, by which the earthy ingredients are dissolved, collecting the remaining charcoal on a filter, washing, drying, and ascertaining its weight; or less accurately by burning the charcoal by calcination in an open crucible, to ascertain the loss. But as its decolorizing property depends more on the quality of its charcoal than its quantity, its value, as such, can only be tested by an actual experiment on a small scale with a test-solution of brown sugar, or molasses, or indigo dissolved in sulphuric acid. To ascertain with accuracy the discoloring effect produced by a certain weight of the bone-black on a certain quantity of a standard solution of one of the above test-liquids, several instruments have been invented, termed, by the French chemists,

Decolorimeters, a more special description of which will be found in the "*Dictionnaire de l'industrie*," under "*Decolorimètre*" and "*Noir animal*."

At Menat, in France, a bituminous schiste is found, which, by charring, furnishes a product of great decolorizing power.

Animal charcoal, which, by use, has lost its decolorizing power, may be employed as a superior MANURE.

BONE-EARTH. *Ger.* Knochenerde. The earthy or inorganic ingredients of BONES (which see); but this name is often synonymous with bone-ash or calcined bones (see BONE-ASH). In animal chemistry this expression is used as synonymous with *earthy phosphates*, and means then that basic phosphate of lime (mixed with a small portion of phosphate of magnesia), which forms the main inorganic ingredient of bones, and occurs in most animal solids and liquids.

BORACIC ACID. *Min.* See SASSOLIN. *Chem.* See BORON.

BORACITE. *Min.* Syn. Tetrahedral B, Mohs; Borate of Magnesia.

Descrip. Cryst. system, Regular. The prevailing form is the cube with the 12-hedron; of the $\frac{1}{2}$ forms, we often find the $\frac{3}{2}$ -hedron and $\frac{2}{3}$ -hedron sometimes combined alone, sometimes one or both with the cube, or with the cube and 12-hedron; these combinations are often very regular. Cleavage imperfect parallel to faces of the 8-hedron.

H. = 7.0. G. = 2.955.

Color white, with a grayish, greenish, or yellowish tint; lustre vitreous, glistening; transparent, subtranslucent; fracture conchoidal; streak white; pyro-electric.

Behavior. Unalterable in a closed tube; on charcoal it intumesces and fuses to a translucent mass; the fused and yellowish bead on congealing crystallizes fibrous on the surface, becoming white and opaque. It colors flame greenish. Borax and mic. salt dissolve it to clear beads, the latter becoming opaque by an intermitting flame; with a certain quantity of soda it dissolves to a clear glass, which presents a crystalline surface on congealing. Soluble in chlorohydric acid.

Analysis. 1. From Lüneburg heath by Arfvedson; 2, from the same by Rammelsberg; a, small transparent crystals; b, larger, opaque, and somewhat disintegrated.

	1.	2 a.	b.
Magnesia	30.3	30.748	31.124
Boracic acid ..	69.7	69.252	68.876
	100.0	100.000	100.000

Formula, $3\text{MgO}, 4\text{BO}_3$, or more properly $\text{MgO}, 2\text{BO}_3 + 2(\text{MgO}, \text{BO}_3)$.

Localities, &c. In the Gypsum formation near Lüneburg, and at Segeberg in Holstein. In the S. of Peru near Tarapaca.

BORAX. *Chem.* See *Borate of Soda* under SODIUM.

BORAX. *Min.* Syn. Biborate of Soda; Tincal; Soude Doratée, Hüuy. *Descrip.* Cryst. system, Right Rhombic.

H. = 2-2.5. G. = 1.716.

Color white, with grayish, bluish, or greenish tint; lustre vitreous, resinous; transparent, opaque; taste feebly sweetish, cooling, saline; rather brittle, with conchoidal fracture and white streak. Its composition, manufacture, uses, &c., see under SODIUM.

BORNEËN, BORNEÖL. See CAMPHOR.

BORNITE. *Min.* See TELLURIC BISMUTH.

BOROCALCITE. *Min.* Syn. Hayesine, *Alger.* Hydroborate of lime. *Descrip.* Occurs in globular masses of an interwoven fibrous structure. H. = 1. Color snow-white; lustre silky; emits a peculiar odor. Before the blow-pipe, it intumesces, gives off water; fusing to a clear colorless bead; with an equal bulk of soda, it forms a clear glass while hot, becoming opaque and crystalline on cooling. It spreads in warm water forming a paste. 1. Analysis by A. A. Hayes; 2, calculation from the formula.

	1.	2.
Boracic acid	46.111	45.85
Lime	18.889	18.72
Water	35.000	35.43
	100	100

Formula, $\text{CaO}, 2\text{BO}_3 + 6\text{HO}$.

Although the formula agrees well with the analysis, 5 eq. water would perhaps agree better with the biborates of potassa and soda. This mineral occurs in the province of Tarapaca in Peru. (*Alger.*)

BORON. *Sym.* B. Eq. 10.8 ($13\frac{1}{2}$, Berz. O. = 100).

Borax is mentioned by Geber in the 10th century. Boracic acid was discovered by Homburg in 1702, and called *sedative salt*. Baron proved in 1752 that borax consisted of boracic acid and soda. Crell in 1800 supposed the acid to contain a substance allied to carbon. The element boron was obtained by Gay-Lussac and Thenard, and by H. Davy in 1808. It is one of the least abundant metallic elements, and always occurs as boracic acid either free or combined.

Prep. 1. Fused and thoroughly dried boracic acid is powdered coarsely, mixed with twice its weight of finely cut potassium, and ignited at a red heat in a tube of glass, iron, platinum, or copper. Boil the mass with very dilute muriatic acid, filter, and wash it with water containing sal-ammoniac to prevent the boron passing through the filter, and then remove the sal-ammoniac by alcohol. The potassium is oxidized at the expense of the oxygen of the acid; the oxide thus formed unites with an undecomposed portion of boracic acid, and the borate of potassa is removed by the dilute acid. 2. Pass fluoride of boron, first, through crystallized boracic acid to remove fluoride of silicon, then over binoxide of lead to remove sulphurous acid, and, finally, over heated potassium, when ignition takes place with a red-dish flame and results in a mixture of boron and fluoride of potassium; the latter is removed with some difficulty by water. 3. Borofluoride of potassium dried nearly at a red heat, powdered, and mixed with an equal quantity of potassium, is warmed gently in an iron tube closed at one end until the potassium fuses,

when the whole is incorporated by a steel wire and then heated to ignition, when a quiet combination takes place resulting in boron and fluoride of potassium. This is washed repeatedly with boiling sal-ammoniac solution as before, ignited in hydrogen to remove fluoboric acid and to condense it, and then repeatedly washed again with water, and dried in a vacuum. 4. Decompose hydrate of chloride of boron at a red heat by hydrogen.

Prop. A dark olive-brown, inodorous, and tasteless powder, which, after exposure to a white heat in a vacuum, contracts and sinks rapidly in oil of vitriol; it does not conduct electricity; is neither fusible nor volatile at a bright white heat in vacuo. Previous to ignition it is soluble in pure water with a dark greenish yellow color, and the solution evaporated leaves a translucent greenish yellow rim on the vessel, which is unaltered boron.

Boron is attacked neither by boiling water, nor alkalies, nor acids, excepting nitric and nitromuriatic acids, which convert it into boracic acid. It has a powerful affinity for oxygen, and, when heated to about 550° in the air, it takes fire, burning with a reddish flame, but at a lower temperature, and with a brilliant light in oxygen, scintillating like charcoal; some boracic acid sublimes, and the rest around the remaining boron protects it from oxidation. When ignited with some alkaline salts it decomposes their acids, sometimes with combustion, salt-peter with deflagration, forming a borated alkali, and separating carbon, sulphur or nitrogen from carbonic, sulphurous, and sulphuric, nitrous and nitric acids. It also decomposes many oxides of the metals proper by ignition, and precipitates gold from the aqueous solution of chloride.

Boracic acid. Syn. Boric acid; Sedative salt; Narcotic Vitriol-salt; *Ger.* Borsäure; Borax-säure. It occurs combined with bases, but most abundantly in a free state in the Lagoons of Tuscany, and in solid efflorescences in the soil near Sasso, hence called *SASSOLIN*.

Manufacture of Boracic acid.

By evaporating the waters of the lagoons by the heat of the volcanic vapors issuing from the soil, Tuscan boracic acid is obtained. These lagoons lie in a circuit of some 25—30 miles in a soil of chalk and sand, from which steam and gases issue with some force. The gases consist, according to Payen, of

Carbonic acid.....	57.30
Nitrogen.....	34.81
Oxygen.....	6.57
Sulphuretted hydrogen.....	1.32

100

The steam and gases carry up mechanically small quantities of clay, gypsum, boracic acid, &c. The temperature of the vapors vary from 206°—212°, or sufficient heat by condensation to heat 5.5 times as much water from 32°—212°.

The places whence the vapors issue are walled in like basins, and situated terrace-like above each other on sloping ground. Fresh water from an adjacent stream is let into the

uppermost, and after condensing the vapors with boracic acid, &c., for 24 hours, is run off into the next lower basin, to condense more acid, and thus passes through 4 or 5 into a reservoir, where the muddy particles deposit. It is then transferred to the leaden evaporating pans, some 12 feet square by 1½ deep, which are so constructed as to employ the heated gases issuing from the soil for evaporation, and some 14 placed terrace-like near each other in two rows of 7 each. The water of 1° to 1½ Beaumé is passed into the upper 8 pans, and after 24 hours, having been evaporated one half, into the next 4, where it is again reduced one half, and finally evaporated to crystallization in the two lowest, where, at a temperature of 170° to 185°, it has a density = 10°—11° B. The liquid is run off into wooden vessels lined with lead, and, after crystallizing, the mother liquor is returned to the two lowest pans, while the crystallized acid is dried in houses by the natural heat of the issuing gases. The daily produce with 14 pans is some 180 lbs. of the commercial acid. The annual produce of 9 such establishments is between 700 and 800 tons, and the natural heat of the gases evaporating 170 millions of pounds of water, producing a saving in wood (suppose *dry hickory*) of 190,000 cords, admitting that 1 lb. will evaporate 5 lb. water, or 150,000 at 4 lbs. water to 1 lb. wood.

The Tuscan boracic acid is said to have contained formerly but 8—10 per cent. foreign matter, while that at present made contains from 20—25 per cent., the nature and amount of which is shown by the following analysis by Wittstein:

Crystallized boracic acid.....	76.494
Silicic acid.....	1.200
Sulphuric acid (combined with boracic).....	1.322
Sulphate of potassa.....	0.369
Sulphate of soda.....	0.917
Sulphate of ammonia.....	8.508
Sulphate of magnesia.....	2.632
Sulphate of lime.....	1.018
Sulphate of alumina.....	0.320
Persulphate of iron.....	0.365
Protosulphate of manganese.....	trace
Chloride of ammonium.....	0.298
Water.....	6.557

100.000

Boracic acid is employed in the manufacture of borax, or *biborate of soda*, to which refer under *SODIUM*.

Boracic acid is usually prepared by dissolving 3 pts. borax in 12 pts. boiling water, adding 1 pt. oil of vitriol and setting it aside to crystallize. Remove the crystals, drain or dry them, redissolve in water, and recrystallize, and finally heat the acid to fusion in a platinum crucible in order to expel the remaining sulphuric acid. Instead of sulphuric, muriatic acid may be used, adding it to the borax solution until it strongly reddens litmus-paper; its excess is more easily removed from the boracic acid by crystallization or by heat.

Prop. The fused acid is a colorless, transparent glass, combining great hardness with a

considerable degree of both brittleness and toughness; inodorous, taste faintly bitterish, and not caustic, feebly reddening litmus, but browning turmeric paper; spec. grav. = 1.83; fusible and very fixed, but rising with the vapor of water or alcohol from its solutions in these menstua.

It crystallizes readily on cooling a hot aqueous solution, in white, pearly, elastic scales, with an unctuous touch; it forms 6-sided laminæ of the oblique rhombic system; spec. grav. = 1.479. One part cryst. acid is soluble in 25.66 pts. water at 66.2°, in 14.88 at 77°, in 12.66 at 99.5°, in 10.16 at 122°, in 6.12 at 144.5°, in 4.73 at 167°, in 3.55 at 189.5°, in 2.97 at 212°. Spec. grav. of the saturated solution at 46.4° = 1.014. It is also soluble in some of the strong acids, particularly sulphuric; it is farther soluble in alcohol and oils. The alcoholic solution burns with a *green flame* which is very characteristic.

By heating the crystallized acid considerably above 212° it loses one half of its water of crystallization, and at a red heat the whole of it with intumescence, a little acid passing off at the same time.

Composition of dry acid.

	H.=1.	O=100.	In 100 pts.	Berzelius.
B.....	10.8	136.2	31.04	31.19
O ₃	24.	300.0	68.96	68.81
BO ₃ =	34.8	436.2	100	100

Cryst. acid.

	H.=1.	In 100 pts.	Berz.	Payen.
BO ₃	34.8	56.31	56	56.66
3 HO.....	27	43.69	44	43.34
BO ₃ , 3 HO =	61.8	100	100	100

Formula of dry acid BO₃, of cryst. acid BO₃, 3 HO, of acid heated above 212°, 2 BO₃, 3 HO.

Borates. The affinity of this acid for bases is but little greater than that of carbonic acid, although at a high heat it expels the more volatile acids; hence, even the bichlorates alkalies have an alkaline reaction. Like silicic acid, it combines in very different proportions with bases, 1 eq. of base uniting with $\frac{2}{3}$, 1, $1\frac{1}{3}$, $1\frac{1}{2}$, 2, 3, 4, or 6 eq. of the acid. The borates are generally fusible to a clear glass, often variously colored by different metallic oxides. With the exception of the alkaline salts, they are all difficultly soluble in water.

Analytic Determination of Boracic acid. The presence of this acid may be ascertained by adding the test to a mixture of 1 pt. fluor-spar and $4\frac{1}{2}$ bisulphate of potassa, and heating it in the inner flame of the blowpipe on platinum wire or foil. If present it imparts a green rim to the flame.

The quantitative estimation of this acid is very difficult. If free, a given weight of oxide of lead may be added to the solution, and after evaporation the increased weight of oxide assumed as boracic acid. In combination, the whole weight being known, that of the oxide is ascertained and the acid calculated by loss. It may be separated from many *metallic oxides* by sulphuretted hydrogen or sulphhydrate of am-

monium; from *oaryta*, *strontia*, *lime*, and oxide of *lead* by sulphuric acid; and the three last sulphates are washed with alcohol. From other bases it is separated, if the compound is decomposable by acid, by moistening the powdered substance with sulphuric acid and placing it in the vessel described under ANALYSIS, p. 185, fig. 25. The boron passes off as terfluoride of boron. If the test contain both silicic and boracic acids, it is treated in the same way, by determining the two from the loss of fluorides of silicon and boron, and then obtaining the silicic acid in the usual way from another portion of the test. If the compound be not decomposable by acid, it may be ignited with carbonate of soda, treated with water, the solution treated with carbonate of ammonia to precipitate a little alumina and silica, evaporated to dryness, decomposed by sulphuric acid, and the boracic acid extracted by alcohol. This method is only approximate.

Sulphuret of Boron. By heating boron to a white heat in sulphur-gas, it burns with a red fire, coating the glass with white and opaque sulphuret of boron. Form. BS₃. It acts violently with water, giving off sulphuretted hydrogen, while boracic acid is dissolved. $BS_3 + 3 HO = 3 HS + BO_3$. By cooling the compound in sulphur-gas, it seems to combine with more sulphur.

Terchloride of Boron. Prep. 1. Pass dry chlorine over very dry boron in an ignited tube, receive the gas over mercury. 2. Ignite a mixture of carbon and boracic acid for an hour in a glass or porcelain tube, and then pass dry chlorine over the ignited mixture. $BO_3 + C_3 + Cl_3 = BCl_3 + 3 CO$.

Prop. A colorless gas, of a very acid taste from generated chlorohydric acid, producing a white cloud in the air; it is rapidly absorbed by water, with which it decomposes into chlorohydric and boracic acids. $BCl_3 + 3 HO = BO_3 + 3 HCl$. One vol. chloride of boron combines with $1\frac{1}{2}$ vol. ammoniacal gas to a saline mass, less volatile than sal-ammoniac. BCl₃ is also absorbed by alcohol.

Terfluoride of Boron. Syn. Fluoboric acid gas. Prep. 1. One part glacial boracic acid and 2 pts. pure fluor-spar, are heated to a white heat in a coated and inclined gun-barrel, and the gas received over mercury. $3 CaF + 7 BO_3 = 3 (CaO, 2 BO_3) + BF_3$. 2. One pt. glacial acid, 2 pts. fluor-spar, and 12 oil of vitriol are gently heated in a glass vessel. The latter method yields a gas containing silicon.

Prop. A colorless, incombustible gas, not supporting combustion, of an extremely pungent odor, reddening litmus powerfully; spec. grav. 2.3124, *Dumas*; carbonizes organic matter rapidly; attracts water powerfully, producing very dense white fumes in moist air. It does not attack glass, and is not decomposed by ordinary metals even at a white heat, but potassium (or sodium) heated in it burns with a reddish flame, absorbing about 3 times as much gas as the hydrogen it evolves from water, and changes apparently into a mixture of boron and fluoride of potassium; it is also absorbed by quick-lime, forming a fusible mass, from which sulphuric acid evolves fluoboric gas.

Water absorbs about 700 times its volume of this gas, evolving heat, attaining thereby a spec. grav. = 1.77; the solution is colorless, oily, fuming, very caustic and corrosive, resembling oil of vitriol; by boiling, it loses $\frac{1}{3}$ of the gas, becoming more fixed, and requiring a much higher temperature for ebullition and distillation. Gmelin views it as a compound arising from a mutual decomposition of the fluoride and water, thus $\text{BF}_3 + 3\text{HO} = \text{BO}_3 + 3\text{HF}$, and terms it Terfluohydrate of boracic acid; Berzelius and others regard it as a combination of water with terfluoride of boron.

Sulphuric acid absorbs about 50 times its volume of fluoride of boron, becoming fuming more thick and oily; diluted with water, it precipitates boracic acid.

Boro-fluohydric acid. If the terfluoride of boron be mixed with more water than in the preceding solution, boracic acid deposits from the solution, being equivalent to $\frac{1}{4}$ of the boron in the fluoride. Berzelius explains the decomposition thus, $4\text{BF}_3 + 3\text{HO} = 3(\text{BF}_3 + \text{HF}) + \text{BO}_3$, so that the new acid is BF_3, HF . When this acid combines with an oxide, the hydrogen forms water with its oxygen while the metal assumes the place of the hydrogen; hence, with potassa it would form borofluoride of fluoride of potassium, analogous to the double metallic chlorides. Gmelin views this acid as a tetrafluohydrate of boracic acid ($\text{BO}_3 + 4\text{HF}$) or a compound of the preceding with liquid fluoric acid, that is, terfluohydrate of boracic acid with fluohydrate of water ($\text{BO}_3, 3\text{HF} + \text{HO}, \text{HF}$), in which, when combined with an oxide, the water HO is replaced by the metallic oxide.

If the acid be allowed to evaporate spontaneously, fluohydric acid is evolved, and the preceding aqueous terfluoride of boron remains; if evaporated with boracic acid, the latter is taken up in proportion as the water disappears, and terfluoride likewise remains.

Borates, Borofluorides, and Borofluohydrates, see under each metal.

BOTRYOGEN. *Min.* Syn. Hemiprismatic Botryogen-salt, *Mohs*; Red Iron-vitriol; Neoprase, *Beud.* *Descrip.* Cryst. system, Oblique Rhombic; combinations are 2 vertical prisms,

the main plain P and 2 lateral planes parallel to it, vert. prism M on M = $119^\circ 56'$; M on 2d vert. prism = $160^\circ 54'$. The two prismatic faces vertically striated. Cleavage parallel to M. Crystals generally small and in globular aggregations with a crystalline surface.

H. = 2.2–2.5. G. = 2.039.

Color deep hyacinth-red, passing into ochreyellow, which is the streak; lustre vitreous; translucent; taste feebly astringent.

Behavior. Intumesces, giving off water, and by ignition sulphurous acid, and then acts to the fluxes like peroxide of iron. Partially soluble in water, leaving an ochrey residue; digested in a close vessel with ammonia, it leaves a greenish black residue of magnetic oxide.

Analysis. From Fahlun, Sweden, occurring with Epsom-salt, by Berzelius:

Ferrous sulphate.....	6.77	6.85
Ferroso-ferric sulphate...	35.85	99.92
Sulphate of magnesia....	26.88	17.10
Sulphate of lime	2.22	6.71
Water and loss	28.28	31.42
	100	100

By disregarding the sulphates of lime and magnesia as not essential, the sulphuric acid has twice and the water three times as much oxygen as the base, whence the formula $3\text{FeO}, 2\text{SO}_3 + 3(\text{Fe}_2\text{O}_3, 2\text{SO}_3) + 36\text{HO}$.

BOTRYOLITE. See **DATHOLITE**.

BOULANGERITE. *Min.* Syn. Plumbostib; Ger. Schwefelantimonblei. *Descrip.* In plumose masses with a crystalline structure. Rather soft. G. = 5.97. Black lead-gray, with metallic lustre, opaque and brittle.

Behavior. Very fusible, evolving antimonial fumes and sulphurous acid, and producing a lead coating on the charcoal. Soluble perfectly in chlorohydric acid with evolution of sulphuretted hydrogen, in nitric acid with a residue.

Analysis. 1. From Mohères, France, by Boulanger; 2, from Nasafeld, Lapland, by Thaulow; 3, from Nertschinsk by Bromeis, and 4, by Brüel; 5, from Ober-Lahr by Abendroth.

	1.	2.	3.	4.	5.
Lead	53.9	55.57	56.29	53.87	55.60
Antimony.....	25.5	24.60	25.04	23.66	25.40
Sulphur.....	18.5	18.86	18.21	19.11	19.05
Iron	1.2	—	—	1.78	—
	99.1	99.03	99.54	98.42	100.05

No. 1 contains, also, 0.9 of copper, and No. 4 contains 0.05 of silver. Formula, $3\text{PbS} + \text{SbS}_3$, or $\text{PbS}, \text{SbS}_3 + 2\text{PbS}$. See **ANTIMONIAL ORES**. Plumbostib is probably the same mineral. The above-named are the principal localities.

BOULDER. *Geol.* When rock masses disintegrate from the action of atmospheric agents, torrents, &c., portions of them resist these influences more or less and are thrown off as masses of variable size. Subjected to the same agents and to attrition during transportation, their sharp edges are rounded off, and they

present more or less rounded masses of stone, often at a great distance from their native beds. Such masses are termed boulders.

BOURNONITE. *Min.* Syn. Diprismatic Dystome-glance, *Mohs*; Endellionite, *Bournon*; Schwarz Spiessglaserz, *Wern.*; Bleifahlerz, *Haus.*; Spiessglanzbleierz, *Klaproth.* *Descrip.* Cryst. system, Right Rhombic; combinations are vertical prisms, several horizontal prisms of 1st and 2d order, several octahedrons and terminal planes of all the axes. Crystals are often found with many of these planes combined, but the prevailing form is a combination

of the 3 terminal planes with a vertical and one horizontal prism of each order; these are often compounded on the plane of a horizontal prism, constituting cruciform crystals. It sometimes occurs granular.

H. = 2.5—3. G. = 5.76—5.8.

Color and streak steel-gray, passing into iron-black; lustre metallic; opaque; brittle with conchoidal fracture.

Behavior. On charcoal it fuses, fumes, and congeals to a black globule; with a strong fire it leaves a slag, which, by treatment with soda,

	1.	2.	3.	4.	5.	6.	7.	8.
Lead.....	42.50	39.0	40.84	42.62	41	41.38	38.9	40.2
Copper	11.75	13.5	12.65	12.80	13	12.68	12.3	13.3
Antimony....	19.75	28.5	26.28	24.23	25	25.68	29.4	28.3
Sulphur.....	18.00	16.0	20.31	17.00	20	19.63	19.4	17.8
Iron.....	5.00	1.0	—	1.20	—	—	—	—
	97	98	100.08	97.85	99	99.37	100	99.6

The empirical formula is therefore $6\text{PbS} + 3\text{Cu}_2\text{S} + 3\text{SbS}_3$, and the rational formula, $3\text{Cu}_2\text{S}, \text{SbS}_3 + 2(3\text{PbS}, \text{SbS}_3)$, which may be written as given under ANTIMONIAL ORES.

Localities, &c. The finest crystals occur at Pfaffenberg on the Harz. Other localities are Clausthal and Andreasberg on the Harz, Gersdorf in Saxony, Kapnik in Transylvania, Servos in Piedmont, Endellion in Cornwall, in Peru, Mexico, &c.

BOVEY COAL. *Geol.* A brown coal or lignite found in England, and named from the place of its occurrence.

BOYLE'S FUMING LIQUOR. *Chem.* See Sulphuret of AMMONIUM.

BRAIN. The brain or encephalon forms the main mass of the nervous system of the higher animals, and is enclosed in the cranium. The brain forms a soft pulpy mass, which is surrounded by several membranes, and consists of an outer, cortical or cineritious, and an inner white or medullary portion, of a white color, and firmer texture. According to Ehrenberg, the cineritious or cortical portion is formed of a granulated mass, consisting of finer and coarser grains, the latter being disseminated through the others, and the whole mass being traversed by a plexus of fine blood-vessels. The gray color is owing to a gray pigment which surrounds the fine globules; the latter appear to be connected in rows by fine filaments, and passing over into hollow, nodulated or varicose, or, according to others, straight tubes, converging towards the base of the brain, but never anastomosing with each other. They contain a peculiar fluid (*liquor nervosus*), and are continued into the spinal marrow and into the nerves.

The brain contains in its composition a large amount of water, which, with its solid ingredients, forms a kind of soft pulp or emulsion. Its solid ingredients are made up of a combination or mixture of uncoagulated albumen with several fatty matters.

According to Couerbe, these fatty matters are in number no less than 5; one oily, which he calls *elëencephole* or *cerebrole* (*Berzelius*),

gives a globule of copper. In an open tube it evolves sulphurous acid and gives a coating of oxide of antimony. Nitric acid dissolves it, forming a blue liquid and leaving oxide of antimony and sulphur; caustic potassa extracts some sulphuret of antimony.

Analysis. 1, from Clausthal, and 2, from Cornwall by Klaproth; 3, from Pfaffenberg on the Harz by H. Rose; 4, from Cornwall by Hatchett; 5, from the same by Smithson; 6, from Pfaffenberg by Sindig; 7, from Alais, and 8, from Mexico, both by Dufrénoy.

and 4 solid, cholesterin, cerebrote, cephalote, and stearoconote. These different fats he separates as follows: the brain is freed from its membranes and from adhering blood, &c., by a small portion of distilled water, after which it is dried, at a low temperature, in vacuo, over sulphuric acid, reduced to a coarse powder, and treated first with pure ether till exhausted by it, and then in the same way with boiling anhydrous alcohol. All the fatty matters are thus extracted, and the residue consists chiefly of *albumen* in its coagulated state, mixed with small blood-vessels and a few inorganic salts, as chloride of sodium, &c.

The ethereal solutions contain more or less of all the fatty matters. They are evaporated to dryness, and the residue treated with boiling alcohol. These alcoholic solutions are separated from the precipitate, which forms on cooling, added to those obtained in the same way by the same liquid from the brain, evaporated together to one-fourth, and left to cool. All these different precipitates from the hot alcoholic solutions contain the two principal solid fats of the brain, *cholesterin* and *cerebrote*, perhaps chemically combined. They are separated by cold ether, which dissolves cholesterin, but leaves the other behind. The concentrated alcoholic mother-liquor contains an oily fat, which on further evaporation separates as oily drops, and was called by Couerbe *elëencephole* (altered by Berzelius to *cerebrole*).

What is left by the treatment of the ethereal residue with boiling alcohol contains, according to Couerbe, two other solid fats, cephalote and stearoconote. Of these, the former dissolves in ether, while the latter remains undissolved in this fluid; its solution in it in the first instance being caused by the presence of *elëencephole*.

Different results from these have been obtained by Fremy. His method of treating the brain consists in boiling it in anhydrous alcohol, and then leaving it for several days in contact with this liquid, the object of which is to remove the water, which prevents the ether from acting on it. By this process the albumen

of the brain is coagulated, and may subsequently by pressure be freed from the alcohol. The substance is then quickly comminuted by trituration in a mortar and extracted by ether, first cold and subsequently boiling. The alcohol with which the fresh brain was treated dissolves merely small portions of olein and margarin, and also traces of oleic and margaric acids. While the main portion of the fatty matters is subsequently dissolved by the ether, and remains on evaporation as a viscid mass (*produit étheré*), from which Fremy extracts the different fatty substances. What remains of the brain after the digestion with hot ether is albuminous matter.

The substances which Fremy thus states to constitute the brain are:

1. *Cerebric acid* in its free state and in combination with phosphate of lime and soda.
 2. *Oleophosphoric acid* in its free state and in combination with soda.
 3. *Olein* and *Margarin*.
 4. Traces of *Oleic* and *Margaric acids*.
 5. *Cholesterin*.
- Besides these fatty matters, the brain contains, 6, *water* and, 7, *albumen*.

Cerebric acid. It is identical with Couerbe's *cerebrote*. But Couerbe did not obtain it in its pure state. Prepared according to his method, it possesses different properties, and leaves, after deflagration with nitre, a residue of phosphate of lime. According to Fremy, this acid is obtained by treating the ethereal residue from the extraction of the brain with a large portion of cold ether. The residue left consists then of cerebric acid combined with more or less soda and phosphate of lime, oleophosphoric acid also in combination with lime or soda, and albumen. By treatment with boiling alcohol, slightly acidulated with sulphuric acid, sulphates of lime and soda and albumen are left undissolved, while cerebric and oleophosphoric acids separate on cooling. They are separated by cold ether, which dissolves the latter, and leaves the cerebric acid. By redissolving it in boiling ether it separates on cooling in its perfectly pure state. It thus forms a white substance consisting of small crystalline grains, is soluble in boiling alcohol, almost insoluble in cold, but soluble in boiling ether. By boiling with water it swells up like starch, but does not dissolve. It does not fuse before at a temperature near that at which it is decomposed. According to Fremy, it contains no sulphur.

The following exhibits the results of Couerbe's analysis of *cerebrote*, and Fremy's of *cerebric acid*:

	Cerebrote. Couerbe.	Cerebric acid. Fremy.
Carbon.....	67.818	66.7
Hydrogen	11.100	10.6
Nitrogen	3.399	2.3
Sulphur	2.138	none
Phosphorus	2.332	0.9
Oxygen.....	12.213	19.5

Cerebric acid combines with bases, and may therefore be considered as a feeble acid. It resembles the fatty acids in being insoluble in water, but differs from them by its difficult fusibility.

Oleophosphoric acid. It is contained in the ethereal solution from the cerebric acid. After evaporation of the ether it remains as a viscid, yellowish mass. It is soluble in ether, and dissolves also readily in boiling alcohol, but is insoluble in cold absolute alcohol, which proves that it is no mixture, but a true chemical combination of olein and phosphoric acid, into which two substances it is convertible by boiling with water or alcohol, especially with the addition of an acid or an alkali. In the latter case the olein is saponified at the same time. Fremy did not succeed in producing it by direct combination from olein and phosphoric acid. The difficulty of obtaining it perfectly pure prevented Fremy from analyzing it. It contains, however, from 1.9 to 2 per cent. of phosphorus.

The *Cholesterin* is obtained by treating the ethereal residue from the extraction of the brain with alcohol mixed with caustic potassa, in order to convert the cerebric and oleophosphoric acids into cerebrate, oleate, and phosphate of potassa. The residue remaining on cooling of the alcohol consists of cerebrate and phosphate of potassa and cholesterin, of which the latter is extracted by cold ether. For the properties of *CHOLESTERIN*, see this.

The presence of appreciable quantities of *oleic* and *margaric acids* in the brain may be shown by extraction with dilute alcohol mixed with a few drops of ammonia.

Couerbe ascribed the softening of the brain to the passage of his *cephalote*, a solid fat into liquid *éléencephole*, which two substances he found to have exactly the same composition. But, according to Fremy, it is owing to the decomposition of oleophosphoric acid, caused by the presence of decomposing organic matter. The softening of the brain is, according to him, a putrefaction more particularly of the albumen.

Couerbe's two new fats, *cephalote* and *stearoconote*, are, according to Fremy, nothing but mixtures of several other substances. *Cerebrote* should thus be a mixture of cerebrate of lime or soda, with traces of albumen and oleophosphoric acid; and *stearoconote*, mostly albuminous matter, mixed with traces of cerebrate and oleophosphate of lime and soda. *Éléencephole* he also states to be a mixture of olein, oleophosphoric acid, cerebric acid, and cholesterin.

Neither Fremy nor Couerbe give any information in regard to the relative proportions of the different fatty substances in the brain.

According to Fremy, the human brain contains:

Albumen.....	7
Fatty matters.....	5
Water	80

All chemical analyses show that the cortical portion of the brain contains more water and less fatty matters than the medullary substance. Fremy even states that the former only contains traces of them, and ascribes the white appearance of the medullary substance to its content of fat. After the extraction of the latter, its color resembles that of the cortical substance.

BRAN.

BRAN.

We subjoin the following analysis of human brain performed by Lassaigue :

	Brain.	Subst. cortic. (Anal. separately.)	Subst. medul.
Albumen	9.6	7.5	9.9
Colorless fat	7.2	1.0	13.9
Red fat.....	3.1	3.7	0.9
Extractive, lactic acid, salts.....	2.0	1.4	1.0
Phosphate of lime, with traces of magnesia and oxide of iron.....	1.1	1.2	1.3
Water	77.0	85.0	73.0
	100	100	100

Brains of Animals. Hog's brain treated after the method of Couerbe (before Fremy's investigations were known), yielded in 100 parts :

Stearoconote.....	none
Cephalote.....	0.60
Cerebrote.....	3.77
Cholesterin.....	3.64
Eléencephole, cholesterin, mixed with other fatty matters	3.38
Ozmazome, lactates, and other sub- stances soluble in absol. alcohol and water	0.76
Extractive matter, salts, and other substances insol. in alcohol but soluble in water.....	1.60
Albumen, with remainder of ves- sels, &c.....	8.61
Water	77.64
	100

The composition of the *spinal marrow* and the *nerves* have, as far as examined, the same general composition as the brain, but contain still more fatty matters, and less albumen and water.

Concretions are sometimes met with in the brain. Such occur frequently within and on the surface of the pineal gland, varying considerable in size from that of a few atoms of grit to larger bodies of irregular shape. They consist, according to John, of phosphate of lime, with a small portion of phosphate of magnesia, and about $\frac{1}{4}$ of their weight of animal matter. Concretions of cholesterin occur also. One analyzed by Lassaigue yielded :

Cholesterin	58.0
Albumen (coagulated).....	39.5
Phosphate of lime.....	2.5
	100

BRAN. *Tech. Syn. Old Fr.* Bren; *Ital.* Brenna; *Ger.* Kleie; *Fr.* Son. The outer husk or skin of grain, particularly of wheat, being separated from the flour after grinding by sifting or boulding. According to Saussure, the ashes of wheat bran contains

Soluble salts.....	44.15
Phosphates of magnesia, &c.....	46.50
Silica and metallic oxides	0.75
Loss	8.60
	100

Runge and Köchlin-Schouch have conducted experiments on bran, with a view to ascertain its value in calico-printing, and the causes of its peculiar action. Runge obtained several different substances from it, with the exact chemical nature of which we are not acquainted, and it is not probable that they are pure. They are brannic acid, bran-gluten, and bran-gum.

Brannic acid. Prep. Wash the bran several times rapidly with water to remove the flour; boil it for 15 minutes with 10 times its weight of water, strain it, evaporate the solution in a water-bath to dryness, and add a little water to it, which dissolves the brannic acid, leaving a swollen glutinous mass. Add strong alcohol to the solution of acid, which precipitates in white flocculæ, filter, dissolve in water, add a solution of sulphate of copper, collect the bluish white brannate of copper and decompose it, suspended in water by sulphuretted hydrogen.

It is white, amorphous, dries to a gummy mass, is insoluble in alcohol and ether, but very soluble in water. It decomposes most metallic salts, forming insoluble compounds with their oxides. It appears from Runge's experiments that bran owes its striking action in calico-printing to this acid; for it produces nearly the same depth of color with alum and sulphate of iron, that the acetates of alumina and iron produce. A decoction of bran (1 bran to 10 water) produces a similar effect, but in a less striking degree. From its power of decomposing salts, if a textile fabric be imbued with it, and then passed through a mordant, it attaches a larger quantity of the oxide or base to the cloth, and hence the depth of color received in the dye-bath. Applied to linen, it enables it to receive color much more readily than without it. Bran-gluten and gum are less interesting.

Bran itself is unquestionably one of the best materials for clearing mordanted goods, the brannic acid probably acting by decomposing the mordant in places where it is not printed, and rendering it inert. It is superior to phosphate of soda by its brightening the colors, without loosening them, and its clearing a white ground more perfectly. As an addition to the dye-stuff, madder, log-wood, &c., it is equally efficient. With madder its action is striking; it prevents too much color from adhering to the first piece dyed, and gives it a more fiery red by removing the brown tint, so that the second appears but a shade lighter than the first; in other words, it diffuses the color and brightens it at the same time; the

first piece passed through a bath precisely the same, but without bran, appears of a deep brownish red, the 2d is many shades lighter, and the 3d piece is a very light rose. The best proportion is 3 bran to 1 madder by weight, but this proportion must vary with the quality of the madder and the object in view.

BRANDY. *Tech.* An alcoholic liquid of some 50 per cent. strength, made by distilling wines. They are distinguished from each other by their peculiar flavor or aroma, arising in part from essential oil previously existing in the fruits from which they are derived, and in part from products generated by fermentation and distillation. Hence a good judge of brandy can determine from what place it is derived, in other words, from what fruit, and may even distinguish minute shades of difference in the quality of different brandies from the same source. In Germany and elsewhere, the term brandy (*Branntwein*, burnt wine) is applied to distilled liquors generally, derived from fermented grain, potatoes, grapes, and other fruit, but in the United States and in England it is usually restricted to distilled wines, or the distilled marc of the grape.

Among the ingredients in wines are sugar, gum, tartaric and acetic acids, free and combined, essential oils, extractive, &c. When they are distilled an oily substance accompanies the alcohol, called *fousel oil*, which imparts a peculiar and usually disagreeable taste and odor to the liquor. This oil usually appears in greater quantity towards the end of a distillation, especially when a low temperature is employed, and hence may be obtained by distilling the residue after the alcoholic liquid is passed over. The fousel oil obtained by Aubergier was a clear liquid of a highly penetrating odor, a sharp and highly disagreeable taste, was soluble in 1000 pts. of water, and a single drop imparted the fousel taste to 15 gallons of well-flavored brandy. Too little is known relative to this substance to remove it perfectly in the manufacture of brandy, and the probability is that fousel oil from different sources will prove very different in composition and properties. See **FOUSEL OIL**.

Cognac and other French brandies owe their agreeable flavor to the smaller amount and less disagreeable nature of their fousel oil, so that the proper aroma of the wine is clearly perceptible in their odor and taste. Oinanthic ether is another constituent which imparts an agreeable aroma to wines, and passes into the brandy. See **OINANTHIC ACID**.

In Cognac, &c., it is probable that the aromatic portion condenses sooner than a strong alcoholic liquid, for the finest kinds are only distilled to the spec. grav. 0.922 at the farthest, and by redistillation to procure a stronger liquor, much of the aroma is lost, or rather remains in the residue. The effect of heat on several of the substances noted above as constituents of wines, merits the attention of the distiller, for a little too high temperature, especially where the still is exposed to the direct action of the fire, is apt to generate empyreumatic and other products, which are unlikely to add to the quality of the liquor.

To manufacture a brandy artificially, add to

about 10 gallons of a pure alcoholic liquid, diluted much below the strength required, a pound of crude argol dissolved in water and a portion of good brandy, and distil the mixture with a gentle heat. Add to the distillate a little acetic ether and color it with burned sugar. Astringency may be imparted by a few drops of tincture of catechu or pure tannic acid. The addition of brandy and crude argol introduces a portion of oinanthic ether, which, with the acetic ether, imparts the peculiar taste of genuine Cognac.

See **ALCOHOL**, **AMYL**, **ARRACK**, **FOUSEL OIL**, **GIN**, **LIQUORS**, **RUM**, **WHISKEY**, **WINE**.

BRASS. *Tech. Syn. Ger.* Messing; *Fr.* Laiton, Cuivre jaune. *Red Brass*, *Tombac*; *Ger.* Rothes Messing, Rothguss. Other alloys are Prince Rupert's metal, Pinchbeck, Similor, Dutch gold, Platin, &c. But of these the two last are only employed at present.

MANUFACTURE OF BRASS.

Brass is an alloy essentially composed of copper and zinc, often containing small quantities of iron, lead, and tin, either as accidental or designed ingredients. It was formerly made by igniting metallic copper with calcined calamine (oxide of zinc) and charcoal, the latter deoxidizing the calamine, and leaving the zinc free to unite with the copper. At present it is chiefly made by the direct fusion of the two metals, in consequence of the improved processes for obtaining zinc.

Older Method. Rosett-copper, bean-shot, or copper clippings are used. Calamine is a carbonate mixed with silicate of zinc and with sand, and is calcined previous to use, to free it from carbonic acid and render it more porous. Roasted blende has also been employed, and was generally used in England as an addition to the calamine, but it is liable to many objections. Many iron blast-furnaces are interiorly incrustated with a firm layer of *cadmia*, or impure oxide of zinc, arising from zinc in the iron-ore, and this was also employed.

The proportions are about 6 parts copper, 6 calcined calamine, and 3 finely pulverized charcoal, which are interstratified in the crucible, and ignited at a strong heat. The produce is $7\frac{1}{2}$ pts. of a half-formed brass, called *Arcot*. The arcot is again ignited with calamine, charcoal, and brass or copper, and when fused, a little metallic zinc is added, which completes the brass. Both of these operations might be condensed into one, but with calamine alone the brass would consist of 80 copper + 20 zinc, which is much too small a content of zinc, and hence the addition of metallic zinc to complete the manufacture. This process has generally yielded to the newer one by direct fusion of the component metals.

Newer Method. An excellent establishment for making brass is at Hegermühl on the Finow-canal near Neustadt-Eberswalde, in Prussia. Charcoal was formerly used, but is now replaced by pit-coal. The furnace is a circular dome, with 7 arched benches, uniting in a key-stone in the centre. The pots or crucibles are placed on the benches, and the flame arising between the benches plays around them. The proportions employed are 51 lbs. old brass (free

from tin and lead solder), 55 lbs. refined and granulated copper, and 24 lbs. zinc, altogether 120 lbs., which is distributed into 4 crucibles. The waste in fusion is $2\frac{1}{2}$ to 4 lbs. ($2-3\frac{1}{2}$ per cent.) The crucibles are carefully made of a good fire-clay mixed with pounded crucibles in the ratio of 2:3. They are 16 inches deep, $9\frac{1}{2}$ wide at the mouth, $6\frac{1}{2}$ at the bottom; with a thickness in the sides of 1 inch and $1\frac{1}{2}$ below; they stand from 40 to 50 meltings. The old brass, which fills their whole capacity, is first put in and melted down; the crucibles are now taken out, and are charged with the half of the zinc in pieces of from 1 to 3 cubic inches in size, covered over with coal ashes; then one half of the copper charge is introduced, again coal-dust; and thus the layers of zinc and copper are distributed alternately with coal-ashes betwixt them, till the whole charge gets finally fused. Over all, a thicker layer of carbonaceous matter is laid, to prevent oxidizement of the brass. Eight crucibles filled in this way are put into the furnace between the 11 holes of the grate shelf; and over them two empty crucibles are laid to be heated for the casting operation. In from $3\frac{1}{2}$ to 4 hours the brass is ready to be poured out. Fifteen English bushels of coals are consumed in one operation; of which six are used at the introduction of the crucibles, and four gradually afterwards.

When sheet brass is to be made, the following process is pursued.

An empty crucible, called a *caster* (*Giesser*), is taken out of the furnace through the crown with a pair of tongs, and is kept red hot by placing it in a hollow hearth (*Mundal*), surrounded with burning coals; into this crucible the contents of four of the melting pots are poured; the dross being raked out with an iron scraper. As soon as the melting pot is emptied, it is immediately re-charged in the manner above described, and replaced in the furnace. The surface of the melted brass in the *caster* is swept with the stump of a broom, then stirred about with the iron rake, to bring up any light foreign matter to the surface, which is then skimmed with a little scraper; the crucible is now seized with the casting tongs, and one end of it resting on an iron upright, it is tilted over until the metal has flowed into the mould. The mould consists of two granite blocks; the upper one, being movable, may be lowered or elevated at pleasure to make a thicker or thinner plate. The casting faces of the slab are covered with as thin a layer as possible of finely powdered loam.

Rolling Sheet-brass. At Hegermühl there are two re-heating or annealing furnaces, one larger, 18 feet long, and another smaller, $8\frac{1}{2}$; the hot chamber is separated from the fire-place by iron beams, in such a way that the brass castings are played upon by the flames

on both their sides. After each passage through the laminating press (rolls) they are heated anew, then cooled and laminated afresh, till they have reached the proper length. The plates are besmeared with grease before rolling.

For wire, the brass is cast in bars, which are treated as in drawing iron-wire, except that they require more frequent annealing.

After rolling, the sheets are covered with black oxide of copper, which is removed by placing them vertically for 5 to 30 minutes in a weak mother-liquor from alum-works, then in a stronger, and rinsing in running water. They are then stretched flat, scraped with a blunt knife, smeared with oil, and finally leveled by a machine like that for planing iron. *Schubarth*.

Composition and Properties. The composition of good brass is about 2 eq. copper to 1 eq. zinc, so that its formula might be $ZnCu_2$, but the relative proportions of these two metals are varied, and small quantities of others are introduced, according to the destination of the brass. A little iron hardens it and diminishes its tenacity and malleability. We usually find traces of tin and lead in it, arising partly from solder in the old brass used in the manufacture, and the lead arising from a small quantity having been in the copper. Tin renders it harder and stiffer, and even a $\frac{1}{2}$ per cent. alters its ductility. The presence of lead renders it better adapted to the lathe, in consequence of the harshness it imparts to it. Pure brass without these metals is very ductile, may be easily drawn into thin wire, rolled, or extended by the hammer.

A small quantity of zinc gives a reddish brass, Tombac; the above formula, $ZnCu_2$, gives a golden color, a larger quantity of zinc produces a greenish yellow, and when the alloy contains more than half zinc, it is bluish gray. The density of the alloy is greater than the mean of that of its constituents.

Copper.	Zinc.	Observed density.	Calculated density.
70	30	8.443	8.390
80	20	8.940	8.560

Tempering diminishes its density, thus the above of spec. grav. 8.94 after tempering was 8.92, another of density 8.344 became 8.250. The same operation also diminishes the tenacity and hardness of brass. The density increases in proportion to the copper, and may even equal that of copper itself, hence it varies between 8.2 and 8.95. Brass expands from 32° to 212° :

Sheet-brass.....	0.001875, <i>Smeaton</i> .
Brass-wire	0.001933
“ “	0.001885, <i>Herbert</i> .

The following table presents the composition of different kinds of brass:

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Copper.....	66	65.8	64.6	65.4	63.7	82	70.1	80	90.5	91.2
Zinc	34	31.7	33.7	33.8	33.5	18	29.9	17	7.9	5.6
Lead	—	2.2	1.5	0.8	0.3	—	—	—	1.6	1.4
Tin	—	0.2	0.2	—	2.5	—	—	3	—	1.8
	100	100	100	100	100	100	100	100	100	100

BRAUNITE.

No. 1 is the composition of a good brass. 2. Brass from Stolberg, Germany; 3, from Jemmapes, France; both of these are adapted to the lathe, and are esteemed of superior quality. 4. Brass-wire from Jemmapes, a soft brass is required free from lead and tin. 5 and 6. Brass or bronze for gilding recommended by D'Arcet for this purpose. This brass should fuse readily, forming a very fluid metal, should chase and turn readily in the lathe, in order to take up as little gold as possible. 7. Is a good brass from Romilly, esteemed as excellent under the hammer, for which purpose it should be, if possible, more ductile than that for wire, 4, and therefore very free from lead and tin. The addition of a little tartar to the fluid metal is said to improve it. 8. This composition is employed in France for ornamenting fire-arms, &c., from its grain, color, and resistance to the air. 9. Chrysocolla. These vary much in composition, but all contain an excess of copper. 10. Statuary brass often confounded with bronze. The composition in the table is that of one of the statues in the palace of Versailles, cast by the brothers Keller.

Besides the above there are various other brasses in common use, passing under different names, which resemble some of the preceding in composition, their different properties, if there be such, being referrible rather to the mode of manufacture and subsequent mechanical processes. *Red brass* or *Tombac* resembles those from 6 to 10. From this and other varieties of metal free from tin and lead, and generally with an excess of copper, *Dutch foil* or spurious gold-leaf is manufactured by hammering. The *Lyons gold-wire* is made by heating thin copper bars or wire in earthen tubes with zinc, the fumes of the latter brazing the copper externally. Vessels may also be brassed externally by boiling them in dilute muriatic acid, containing argal and zinc-amalgam. For brass or *hard solder*, 2 pts. brass are melted with 1 pt. zinc, or 4 pts. copper to 5 zinc, to which a little tin is sometimes added. The solder may be made harder by using less zinc.

Decomposition. Good brass fuses at about 1869° (*Daniell*) or twice the temperature of a red heat; at this temperature it loses a considerable quantity of zinc, which burns off, but even at a white heat there remains 16 per cent., and at a long-continued white heat some 3—4 per cent. By a careful calcination in the air the whole of the zinc may be burned off. It oxidizes in moist air, forming a coating of carbonate; it is easily dissolved by acids, and hence there is some danger in employing it for some domestic utensils. By treatment with dilute muriatic acid, zinc is extracted, and it assumes a darker color. With caustic ammonia it becomes paler. Various shades of color may be imparted to brass by plunging it in mixtures of sulphuric acid and nitre. See farther **BRONZE, COPPER, ZINC.**

BRAUNITE. *Min.* Brachytypous Manganese-ore, *Mohs.* *Descrip.* Cryst. system, Quadratic; the two angles being 109° 58' and 108° 39', it is closely allied to the regular system. Combinations are several sharper and obtuser octahedra of the 1st order; cleaves parallel to

BRAZIL-WOOD.

the radical octahedron. Occurs also massive, fibrous.

H. = 6—6.5. G. = 4.8—4.9.

Color and streak brownish black; lustre sub-metallic; opaque; brittle; fracture uneven.

Behavior and Analysis. Anhydrous, infusible, giving the reaction of oxide of manganese with borax, mic. salt, and soda. Soluble in muriatic acid, evolving a little chlorine, leaving sometimes a siliceous residue. Turner's analysis of B. from Elgersburg in Thuringen Forest gave—

Manganese	67.439
Oxygen.....	29.352
Baryta.....	2.260
Water.....	0.949
Silica.....	trace

100

Its formula is therefore Mn_2O_3 . It occurs in veins in Porphyry at Oehrenstock near Ilmenau, at Elgersburg, &c., in Thuringen; and with red Epidote at St. Marcel in Piedmont.

BRAZING. *Ger.* Messing-löthung. *Fr.* Braser. The soldering together of edges of iron, copper, brass, &c., with an alloy consisting of brass and zinc, sometimes with a little tin or silver. The surfaces to be thus united must be filed perfectly bright, and not be soiled with the fingers or in any other way. The granular or nearly pulverulent alloy is usually wetted with a paste of ground borax and water, applied in this state, dried, and then exposed carefully to bright ignition at a clear forge fire. Some workmen enclose the part to be soldered in a clay lute, but others prefer leaving it uncovered, that they may see when the solder has flowed freely, and entered into all the seams. (*Ure.*)

BRAZIL-WOOD. *Fr.* Bois de Fernambouc. *Ger.* Fernambuk or Brasilien-holz. A red dye-wood obtained from different species of *Cæsalpinia* growing in the Brazils in South America and in the West Indies. Several varieties are known in commerce. 1. The proper *Brazil-wood* said to be derived from *Cæsalpinia echinata* and sometimes called *Pernambuco* or *Fernambuca-wood* from the province of Brazil, where it is collected. 2. The *Brasilletto* obtained from *C. Braziliensis* and *Crista*, which grows in Jamaica and other parts of the West Indies. The former is the most highly valued. 3. The *Sappan* or *Sampfen* wood obtained from *C. Sappan* possesses properties analogous to those of the *brasilletto*, as does also 4. *Nicaragua* or *peach-wood*. *Brazil-wood* is nearly inodorous, has a slightly sweetish taste, and a pale red color, when newly cut, but which becomes deeper by exposure to air. It is hard, and heavier than water, to which latter it imparts its coloring matter. It contains, besides a coloring matter called *Brasilin*, an essential oil, having the taste and odor of pepper, free acetic acid, acetates, and other salts.

A decoction of *Brazil-wood* produces a red precipitate with protochloride of tin, and a dark violet with sulphates of copper and iron. The principal use of *Brazil-wood* is in dyeing; a red

lake is prepared from it. It is also an ingredient of red ink. Its colors are but of little permanency, fading by the influence of air and light. Soap and alkali change them into a dark blue or purple.

BRAZILIN. *Fr.* Bresiline. Discovered by Chevreul, prepared by extracting Brazil-wood with water, evaporating to dryness; treating the mass with alcohol, evaporating the alcohol after the addition of some water, precipitating with a solution of glue, filtering, evaporating, and treating the residue with alcohol, from which the brazilin crystallizes.

It forms small orange-colored needles, soluble in water, alcohol, and ether. Its solution is reddish yellow, becoming yellow by a small addition of acid, and red by the addition of more, by alkalis it becomes blue or violet; is entirely decolorized by sulphuretted hydrogen and sulphurous acid gas. It combines with bases to purple or violet combinations; yields precipitates of the same color with oxides of lead and tin, and a crimson red with alum. Is partly volatilized by heat.

BREAD, a food prepared from the meal or flour of the cerealia, by kneading it together with water into a dough, and exposing it to the action of heat, or baking it. There are two principal kinds of bread, *fermented* or *leavened*, and *unfermented* or *unleavened*. For the fermented or leavened bread, the dough is first made to undergo a kind of fermentation by the addition of *leaven* or dough, which is already in a fermenting state, or of *yeast*. The first is more uncertain and slow, and is apt to impart a sour taste. The *panary fermentation* seems to be an alcoholic fermentation of the same nature as that of saccharine matters, by which alcohol and carbonic acid are generated, which latter remains enclosed in small bubbles by the toughness of the gluten, and thereby raises the dough. The latter is then again kneaded over with some fresh flour, moulded or shaped into different forms, and after having been kept for a short time in a warm place to induce a new fermentation, by which they swell up to about double their original size, they are then *baked* or subjected to the action of heat in an oven, by which they still more enlarge by the dilatation of the enclosed carbonic acid, and become light and porous. Along with carbonic acid traces of alcohol are at the same time produced, but not in sufficient quantity to be worth collecting for economical purposes. By the panary fermentation not only a portion of the *amylum* passes into the saccharine state, and from thence into carbonic acid and alcohol, but a mutual action seems at the same time to take place between the rest of the *amylum* and the gluten, by which they lose their tenacious and glutinous character, and become more palatable and digestible. This change is still more increased by the subsequent baking, which puts a stop to all further fermentation or change by exposure to the elevated temperature and the evaporation of a great portion of the water. Good fermented bread can therefore only be made of such flour as contains a sufficient quantity of gluten, otherwise the bread becomes heavy, unpalatable, and indigestible. Wheaten flour affords, in this point,

the best bread, and more or less of it is generally added to other kinds of flour for fermented bread.

Biscuit forms the best kind of unleavened or unfermented bread, the dough of which is not subjected to any fermentation previous to being baked.

Bread forms a main article of food. The best is made from wheat. *Fine* bread prepared from flour only (bolted) is the most nutritive and digestive, that which contains the *bran* is laxative, and therefore preferable to persons troubled with habitual constipation. *Rolls* and other kinds of *fancy bread* are less digestible than common loaf bread. All kinds, when eaten new, are injurious to dyspeptics. Unleavened bread sometimes suits the stomach of such people when leavened bread disagrees. That which is free from butter is to be preferred.

In baker's bread, which is always whiter than homemade bread, small quantities of alum are said to be mixed into it, with the view of whitening or bleaching it. According to Accum (on the adulteration of food), the smallest quantity for this purpose is from 3 to 4 ounces to a sack of flour, or 240 lbs. of flour, but is increased in proportion to the inferiority of the flour. If so, it must be considered as an injurious addition, occasioning constipation, &c. Another article occasionally employed in bread-making, in order to make it lighter, and to neutralize any acid that may have been formed, is carbonate of ammonia. It being entirely dissipated by heat, its use may be considered perfectly harmless. Of injurious adulterations, small quantities of sulphate of copper are said sometimes to have been added to bread in order to improve its color. The most nefarious adulteration of bread consists in the addition of certain insipid and colorless earthy substances, with a view of increasing its weight, such as pipe clay, porcelain clay, chalk, plaster of Paris, &c. All these adulterations are easily detected by incineration in a crucible, by which they are left behind, and may be examined. For ordinary purposes, the experiment may be performed by dissipating a portion of the bread over a coal-fire on a fire-shovel, when the adulterations are left behind.

BRECCIA. *Geol.* A conglomerate, composed of angular fragments of rocks imbedded in or cemented by siliceous, calcareous, or ferruginous matter, is termed breccia. In many instances the fragments and cement are so firmly united that the rock may be broken, cut, and polished as a whole. Some parts of the Potomac marble, having angular fragments, is a breccia. See CONGLOMERATE.

BREISLAKITE. *Min.* Occurs in flocculæ of delicate flexible capillary crystals of a chestnut brown color, and with a metallic lustre. It contains silica, alumina, and iron; little else is known of its chemical character. It has been observed at Vesuvius, and Cape di Bove near Rome, forming woolly flocculæ in cavities of lava, and accompanying Nephelin and Augite.

BREVICITE. *Min.* Occurs in transparent prisms, and foliated, in the trachytic rock of Brevig, in Norway. It acts like other zeolites,

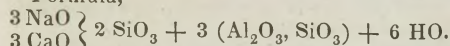
BREWING.

giving off water, and fusing to a colorless, vesicular glass. Sonden's analysis gives

Silica.....	43.88
Alumina.....	28.39
Soda.....	10.32
Lime.....	6.88
Magnesia.....	0.21
Water.....	9.63

99.31

Formula,



See MESOLE and MESOTYPE.

BREWING. *Tech.* The technical processes by which malt-liquors are manufactured. Refer to BEER.

BREWSTERITE. *Min. Syn.* Megallogonous Kouphone-spar, *Haid.* *Descrip.* Cryst. system, Oblique Rhombic. Combination, the vertical prism with 1st and 2d lateral planes, the oblique terminal plane and its oblique prism.

Term. plane on 2d lateral plane = 93° 40'

“ “ “ its oblique prism = 176°

The oblique prism = 172°

Cleaves perfectly parallel to 2d lateral plane.

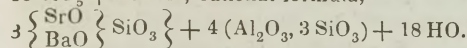
H. = 5—5.5. G. = 2.12—2.4.

White, yellowish; lustre of 2d lateral plane, pearly, the others vitreous; transparent, translucent; streak white; fracture uneven.

Behavior and Analysis. In behavior, it resembles the zeolites, giving off water, frothing, fusing, and leaving silica in mic. salt. Soluble in acids, leaving gelatinous silica. Analyzed, 1, by Connel from Strontian; 2, by Thomson:

	1.	2.
Silica.....	53.66	53.05
Alumina.....	17.49	16.54
Baryta.....	6.75	6.05
Strontia.....	8.32	9.00
Lime.....	1.35	0.80
Peroxide of iron.....	0.29	—
Water.....	12.58	14.74
	100.44	100.18

Empirical formula, $\text{BaO} + 2\text{SrO} + 4\text{Al}_2\text{O}_3 + 15\text{SiO}_5 + 18\text{HO}$; rational formula,



Localities. Strontian in Scotland; Giant's Causeway; lead mines of St. Turpet, near Freiburg in the Brisgau; in depart. of Isère in France; in the Pyrenees.

BRICK. *Ger.* Backstein, Ziegelstein; *Fr.* Brique. A solid body of rectangular, or any other shape, made of clay and burned, and used for the construction of walls or other building purposes. Clays fit for the manufacture of bricks occur widely extended. For the chemical composition of pure clay and its different chemical properties, see under CLAY and POTTERY.

For the manufacture of bricks, the clay is dug and heaped in the fall, exposing it during the whole winter to the action of the atmosphere and, more particularly, to that of the

BRICK.

frost, in order to crumble it down, or to *mellow* it. It is then *tempered* or worked over in heaps, being, at the same time, watered and left to soak for several days, and at last kneaded by the treading of men or oxen. The latter operation is the most laborious, but also the most important, on which, in a great measure, the quality of the bricks depends. The clay is then brought to the bench of the moulder, who dashes a sufficient quantity into the mould, which consists of a rectangular frame or box, without bottom or top, and made of wood or iron. The brick is then carried away in the mould and dexterously shaken out of the mould in rows on a prepared ground or *floor*. In order to prevent the bricks from adhering to the mould or the ground, both are sprinkled with fine dry sand. When they have acquired sufficient firmness to bear handling, they are brought under a shed and piled on edge into open hollow walls, so as to admit the air freely between them. Those which require a more accurate shape, as when intended for front walls of houses, are pressed in a press on their removal from the ground. A first rate moulder has been known to deliver from 10,000 to 11,000 bricks in a long summer's day, but the average produce is not more than half this number, depending more or less on the quality of the brick.

When sufficiently dry, the bricks are burned in a kind of furnace, generally called kiln, consisting merely of four walls, being open on the top, and having at the bottom, on two opposite sides, arched openings, through which the firing is performed by throwing in the fuel (generally wood). The bricks are piled inside the kiln, so as to form arched flues from the fire-openings on the one side to the openings on the opposite, from which the flame then penetrates through all the bricks in the kiln, being piled on edge so as to leave interstices between them. In England bricks are often burned in clamps built of air-dried bricks instead of burned bricks. In burning bricks the heat must at first be gentle, to finish the drying and prevent the bricks from cracking or warping; the heat is then gradually increased till the upper layers become red-hot, after which the fire is abated, and at last suffered to go out. The bricks in the lower part are burned harder and are of a darker color; those towards the top of a lighter color. One firing will last, according to the size and construction of the kiln, from 24 hours to 6 or 8 days. Burning in clamps, from 20 to 30 days.

The ingredients which form the constituents of brick-clay are clay and sand, with small portions of lime and oxide of iron. On the clay depends its plasticity and property of hardening by burning; but without a sufficient quantity of sand it would be apt to warp and crack by the drying and burning. Lime and oxide of iron render the mass more fusible, and therefore capable of cementing and hardening at a lower temperature. The red color of bricks depends on their content of oxide of iron. Calcareous clays generally yield bricks of a yellowish or light color and harder, but less capable of withstanding heat without speedy fusion. These different ingredients of

BRIGHTENING.

brick-clay are very often found in the right proportions, but can sometimes only be obtained by mixing different clays, or by adding more or less of one of the ingredients. Where the clay is very plastic it is necessary to mix it with more sand to prevent it from cracking and warping. Calcareous clays are often mixed with coal ashes.

Fire-bricks are made of the finest varieties of clay nearly free from oxide of iron and lime, and burned by a higher heat in potters' kilns.

Scouring-bricks are made of extremely fine sand and clay, both previously freed by *washing over* from all coarser particles, and mixed together in the right proportion and burned.

Floating-bricks is the name of a variety of bricks so light as to float on water. They are made of a peculiar light magnesian earth sometimes called *fossil-meal*. They resemble common bricks in appearance, but are of a whiter color and much lighter. Floating-bricks are mentioned by Pliny and other ancient writers.

The goodness of bricks depends on their hardness, porosity, fusibility, and power of resisting exposure to atmospheric agencies, according to the purpose for which they are intended.

BRIGHTENING. *Ger.* Schönung. *Fr.* Aviver, éclaircir. *Tech.* A process in dyeing, by which the dyed goods receive a final treatment before finishing, in order to render the colors more brilliant or to alter their tone. It is generally done by passing them through a dilute solution bath, of a substance producing the desired effect. The chemical nature of coloring matters being extremely different, the brighteners necessarily vary. The most frequent are a hot or cold soap or alkaline bath, tinsalt, &c.; acids are rarely used.

BRILLIANT. A name sometimes applied to gems, especially to the diamond.

BRIMSTONE. *Tech.* A common appellation for sulphur, becoming obsolete. See **SULPHUR**.

BRITHYNE-SALT. *Min.* See **GLAUBERITE**.

BRITISH GUM. *Syn.* Torrefied or roasted starch; *Ger.* Geröstete Stärke; *Fr.* Amidon torréfié. It is obtained by slightly heating starch in close vessels. Well dried starch (or even potatoes) is heated to 300° in sheet-iron trays, when it puffs up, giving off vapors and the odor of highly baked bread, and forming yellowish brown masses. It is ground into fine flour, and thrown in this state into the market. It is thus converted into a gummy substance, soluble both in cold and hot water, forming a thick solution, and hence its use by calico-printers for thickening various mordants or thin solutions in order to print them. See **CALICO-PRINTING** and **STARCH**.

BRITTANIA METAL. *Tech.* Various alloys of tin, with lead, copper, antimony, &c., are employed under the names of Pewter, Britannia Metal, Queen's Metal, in which the proportion of the component metals is different for the different alloys, and even variable for an alloy of the same name, according to the experience of the manufacturer. See *Alloys of TIN*.

BRITTLE SILVER. *Min. Syn.* Prismatic Melane-glance, *M.* Brittle Silver Ore or

BRITTLE VITREOUS SILVER.

Glance; Black Silver; *Ger.* Sprödglasserz; *Fr.* Argent-Antimonié Sulphuré noir. *H.*

Description. Cryst. system, Right Rhombic. Comb. vertical prism, with terminal planes of lateral axes, terminated by the rhombic 8-hedron and a 1st horizontal prism; frequently compounded like Arragonite. Cleavage imperfect, parallel to 1st horizontal prism and 1st terminal plane. It also occurs as a loosely cohering granular mass.

H. = 2-2.5. *G.* = 5.9-6.4.

Color and streak iron-black; lustre metallic; sectile; fracture uneven.

Behavior. In an open tube it fuses, giving a coating of antimony, and sometimes crystals of arsenious acid; on charcoal it produces a faint white coating, often with arsenical odor, yielding a dark gray metallic button, which, with the addition of soda in the reducing flame, leaves a globule of silver. It is wholly decomposed by nitric acid, partially by potassa. *H.* Rose's analysis of brittle silver from Schemnitz gave

Silver.....	68.54
Antimony.....	14.68
Sulphur.....	16.42
Gangue.....	0.64

100.28

Formula = 6 AgS + SbS₃. See **ANTIMONIAL ORES**.

Localities. This valuable ore of silver occurs with other silver ores at Freiberg, Schneeberg, Annaberg, Johaun-Georgenstadt, in Saxony; Przibram, Ratiboritz, Joachimsthal, in Bohemia; Andreasberg on the Harz; Schemnitz, Kremnitz, in Hungary; Zacatecas in Mexico, &c. Werner's Schwarzgültigerz includes the compact varieties, while his Weissgültigerz is a mixture of brittle silver, galena, and gray antimony.

BRITTLE VITREOUS SILVER. *Min. Syn.* Antimonial Sulphuret of Silver; Peritinous Antimony-glance, *Mohs*; *Ger.* Schilfglasserz.

Descrip. Cryst. system, Right Rhombic; the radical 8-hedron not observed; combinations are several vertical and 2d horizontal prisms, and a 1st horizontal prism, parallel to which its cleavage is perfect. The main vert. prism with term. plane gives a 6-sided prism, often with term. plane of main axis. Main vert. prism = 99° 48', *Hausmann*; 100°, *Phillips*.

H. = 2-2.5. *G.* = 6.196, *Hausm.*

Color silver and steel-gray to dark lead-gray; lustre metallic, splendid; not very brittle, with an imperfect conchoidal fracture.

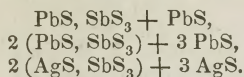
Behavior and Analysis. On coal it gives off sulphurous odor and white fumes, producing a coating of antimony and lead, leaving a button of silver, which sometimes yields copper to borax. Wöhler's average analysis of this mineral from Freiberg gave

Silver.....	22.93
Lead.....	30.27
Antimony.....	27.38
Sulphur.....	18.74

99.32

BROCHANTITE.

Wöhler proposes the formula $\{3 \text{ AgS, SbS}_3 + 2 (3 \text{ PbS, SbS}_3)\} + \{2 \text{ AgS, SbS}_3 + \text{PbS, SbS}_3\}$, in which the 1st member is Ruby silver, the 2d Boulangerite, the 4th Zinkenite, and the 3d is unknown. Berzelius proposes the formula,



in which the 1st is Feather ore, and the others unknown.

Localities. Freiberg, Saxony; Kapnik, Transylvania.

BROCHANTITE. *Min.* Syn. Basic Sulphate of Copper. *Descrip.* Cryst. system, Right Rhombic. Comb. vertical, 1st and 2d horizontal prisms, and terminal planes of axes, that of the main axis being usually large, giving a tabular crystal; vert. prism = $114^\circ 20'$, with dull, blackish surface, and cleavage imperfect parallel to it.

H. = 3.5–4. G. = 3.78–3.87.

Color emerald green; transparent; lustre vitreous; sometimes pearly. *G. Rose.*

Behavior and Analysis. Fuses on charcoal to a malleable globule of copper; in an open tube gives off water and sulphurous acid; fused with excess of soda, and moistened, it leaves a brown stain on silver; with borax and mic. salt, it gives the usual reaction of copper. It is insoluble in water, soluble in acids. (*Magnus.*)

The two analyses are by Magnus, of B. from Retzbanya in Hungary.

Oxide of copper.....	62.626	66.935
Sulphuric acid.....	17.132	17.426
Water	11.887	11.917
Oxide of tin.....	8.181	3.145
Oxide of lead.....	0.030	1.048
	99.856	100.471

Omitting the oxide of tin, which is variable, a little Red Copper ore and Malachite, its formula is $3 \text{ CuO, SO}_3 + 3 \text{ HO}$.

Local. Retzbanya, in Hungary; Ekatherinenburg, Siberia. It is probably the same with the mineral examined by Children from the latter locality. Berthier analyzed a granular, earthy mineral, of a verdigris-green, color from Mexico, which is allied to Brochantite. He found oxide of copper 66.2 + sulphuric acid 16.6 + water 17.2, which leads to the formula, $4 \text{ CuO, SO}_3 + 4 \text{ HO}$, *Rammelsberg*. Forchhammer described at the meeting of Scandinavian Naturalists a mineral from Krisuvig in Iceland, which he termed *Krisuvigite*. It is of an emerald-green color, and consists of oxide of copper 18.88 + sulphuric acid 67.75 + water 12.81 + oxide of iron and alumina 0.56, which approaches the form., $4 \text{ CuO, SO}_3 + 3 \text{ HO}$. *Berz. Jahresb.* xxiii. 264.

BROGNIARTIN. *Min.* See GLAUBERITE.

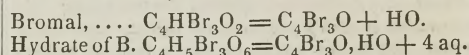
BROMAL. *Chem.* Discovered by Löwig. Formed by the action of bromine on alcohol and ether. *Prep.* To 1 pt. absol. alcohol in a retort surrounded with ice, add 13.8 pts. bromine through a funnel-tube in the tubulure, in small portions, as soon as each portion added disappears, and the mixture cools; warm the liquid, then add 3 times the volume of the mix-

BROMINE.

ture of concent. oil of vitriol and distil. Bromohydric acid, bromine, and bromide of ethyl first pass over, lastly pure bromal, which is purified similarly to chloral, to which refer.

Prop. A colorless, oily liquid, of a peculiar pungent odor, attacking the eyes, and a sharp, acrid taste; spec. grav. = 3.34; boils above 212° ; does not act on vegetable colors; dissolves sulphur and phosphorus; is soluble in water, alcohol, and ether; is decomposed by chlorine and fuming nitric acid; with caustic alkali it produces bromide of the metal, perbromide of formyl, and an alkaline formiate.

Hydrate of Bromal. An aqueous solution of bromal, by slow evaporation in the air, produces large, regular crystals, transparent, colorless, and camphor-like, similar in form to blue vitriol, fusible by a gentle warmth. Formula,



BROMATES, BROMIC ACID, BROMIDES.

See BROMINE.

BROMIC SILVER. *Min.* In the district of Plateros, in Mexico, among the horn silver ores (chloride of silver) of the mine San Onofre, are small grains and crystals, externally green, internally yellow, which Berthier proved to be pure bromide of silver, AgBr. It is associated with chloride of silver, carbonate of lead, and oxide of iron.

BROMINE. Syn. Bromium; *Ger.* Brom; *Gr.* *βρωμος*, smell. Sym. Br. Equiv. 78.4 (978.31, O = 100), *Berz.*; 75.76, *Löwig*; 75.288, *Liebig*. Discovered in 1826, by Balard of Montpellier. Bromine in its chemical relations bears a close analogy to chlorine and iodine, and is always associated with the former, sometimes with the latter. It exists in sea-water in the form of bromide of sodium or magnesium, but its relative quantity is very minute; and even *bittern* contains it in small proportion. It has been detected in the waters of the Mediterranean, Baltic, North Sea, and Frith of Forth; in the waters of the Dead Sea; in a variety of salt and mineral springs in Germany, Switzerland, England, at Saratoga, and in salines in the United States, in New Grenada, &c.; in marine plants growing on the shores of the Mediterranean, on the coast of Holland; in the ashes of some animals, especially in those of the *Janthina violacea*, one of the testaceous mollusca.

Prep. Bromine is usually extracted from *bittern*. Transmit a current of chlorine gas through *bittern*; the free bromine immediately communicates an orange-yellow tint to the liquid; an excess of chlorine must be avoided; then agitate a portion of sulphuric ether with the liquid, which dissolves the whole of the bromine, assuming a beautiful hyacinth-red tint, and on standing rises to the surface. Agitate the ethereal solution with caustic potassa to form bromide of potassium and bromate of potassa; evaporate to dryness, and ignite, to convert the whole into bromide of potassum, and distil with sulphuric acid and peroxide of manganese.

Prop. At common temperatures it is a liquid, between -2° and -13° congealing to a yellowish brown, brittle, lamellar, crystalline mass; spec. grav. 2.98 at 59° ; color blackish

red, when viewed in mass and by reflected light, but hyacinth-red in a thin stratum of transmitted light. Its odor, somewhat resembling chlorine, is very disagreeable, and its taste acrid and astringent. At common temperatures it emits red-colored fumes, very similar to those of peroxide of nitrogen; and at 113° it enters into ebullition. Spec. grav. of its vapor = 5.54, *Mitscherlich*; by calculation = 5.3930: 100 cubic inches at 60° and 30 inches B. should weigh 167.25 grains. It is a nonconductor of electricity, and suffers no chemical change from the imponderables, or by being transmitted through a red-hot glass tube. It is soluble in 33.3 water at 59° , the solution remains fluid at -4° , and loses all bromine by heat; soluble in alcohol, much more in ether, but it changes these bodies; see **BROMAL**. It does not redden litmus paper, but bleaches it and a solution of indigo like chlorine. Its vapor extinguishes a lighted taper: which burns for a few seconds with a flame greenish at its base and red above. Antimony and tin take fire in bromine; and potassium produces intense heat and a vivid flash of light. It acts with energy on organic matters, such as wood or cork, and corrodes the animal texture; if a little be applied to the skin it communicates a transient yellow stain, but in larger quantities causes violent inflammation. One drop of it placed in the beak of a bird proved fatal.

Hydrate of Bromine. By exposing a mixture of much bromine with a little water to 32° it forms regular octahedra of a hyacinth-red color, which separate again into bromine and water at 59° . Formula, Br, 10 HO, or $46\frac{1}{2}$ per cent. bromine.

Use. Bromine has been latterly employed to a limited extent in medicine; much more extensively in the Daguerreotype, to obtain a surface of silver more sensitive to the decomposing action of light.

Analysis. Bromine is tested, as described under its preparation, by passing chlorine through a solution supposed to contain it, when a brownish yellow color indicates its presence; the color may be farther concentrated by shaking with ether. Its quantity is determined by precipitating it as bromide of silver. It is separated from iodine by adding chloride of palladium, which precipitates iodide of palladium. From chlorine it cannot be separated accurately, the best method being to precipitate by nitrate of silver, weigh the fused bromide and chloride, then to pass chlorine over a weighed quantity of the latter, which converts the whole into chloride, and to calculate, from the difference in weight compared with the equivalents of chlorine and bromine, the quantity of bromine.

Bromohydric acid. Syn. Hydrobromic acid; Ger. Bromwasserstoffsäure.

Prep. No action takes place between bromine and hydrogen at common temperatures, not even by the direct solar rays; but on introducing a piece of red-hot iron, combination ensues in the vicinity of the heated body, though without extending to the whole mixture, and without explosion. It decomposes water slowly by sun-light. It decomposes some of

the gaseous compounds of hydrogen, iodohydric acid, sulphuretted or phosphuretted hydrogen gas, and liquid ammonia forming bromohydric acid. 1. It may be made by combining bromine and phosphorus, and slightly moistening it, when it yields, by the aid of gentle heat, pure bromohydric acid gas, which should be collected over mercury. 2. Warm a mixture of 1 phosphorus, 12.5 bromine and 7.8 of bromide of potassium with a little water. $\text{KBr} + 5 \text{Br} + \text{P} + 6 \text{HO} = \text{KO}, \text{PO}_5 + 6 \text{HBr}$.

Prop. A colorless gas, of a very acid taste, and pungent odor, exciting coughing; it yields white vapors when mixed with moist air. Spec. grav. 2.75. Its solution in water is made by transmitting a current of bromohydric acid gas into pure water; which becomes hot during the condensation, acquires great density, and increases in volume, or it may be made as the gas above, without distillation. It emits white fumes when exposed to the air; is colorless when pure; spec. grav. of the densest solution = 1.29; the latter boils below 212° , but the feebler acid above; it dissolves a large quantity of bromine, receiving a brownish tint. It undergoes no decomposition in a red-hot tube, either alone, or mixed with oxygen. It is not affected by iodine; but chlorine decomposes it instantly, with production of hydrochloric acid gas, and deposition of bromine. It may be preserved without change over mercury; but potassium and tin decompose it with facility, the former at common temperatures, and the latter by the aid of heat. Nitric acid acts upon it at first slowly, then rapidly, producing bromine, water, and peroxide of nitrogen. Nitro-hydrobromic acid dissolves gold; sulphuric acid produces, with hydrobromic, sulphurous acid, water, and bromine. Most basic metallic oxides decompose it by heat into a metallic bromide and water; those of lead and silver in the cold. Metallic acids and hyperoxides effect a similar change with the liquid acid.

Composition.

Br.....	78.4	98.74
H.....	1	1.26
HBr.....	79.4	100
	Vol.	Spec. grav.
Br. vapor.....	$\frac{1}{2}$	2.71775
Hydr. gas.....	$\frac{1}{2}$	0.03465
	1	2.75240

Bromhydrates, Bromides. They are formed, 1, directly by contact of the metal with liquid or gaseous bromine, as potassium, arsenic, antimony, and tin, with combustion; bismuth, iron, and mercury at common temperatures without, and by heat with combustion, gold unites slowly; 2, by bromohydric acid and most metallic oxides, thus, $\text{PbO} + \text{HBr} = \text{PbBr} + \text{HO}$; or even some metals, with evolution of hydrogen, thus zinc, $\text{Zn} + \text{HBr} = \text{ZnBr} + \text{H}$; 3, by a soluble bromide and a metallic salt, where the bromide of the latter is insoluble.

The bromides closely resemble the chlorides in appearance, and are isomorphic with them.

BROMINE.

Bromine forms soluble and insoluble compounds with the same metals as chlorine.

Bromine and Oxygen. Bromine and oxygen do not unite directly, but in the same manner as chlorine and oxygen, forming bromic and probably hypobromous acid.

1. *Hypobromous acid.* This acid appears to be formed like the hypochlorous, for, on adding bromine to an excess of caustic or carbonated potassa, but little bromic acid is formed, and the liquid seems to contain bromide of potassium, hypobromite of potassa and free alkali, for it smells like the chlorine-salt, bleaches litmus and indigo, develops nitrogen from ammonia and free bromine by acids. Form. BrO (?)

2. *Bromic acid.* It is formed similarly to the chloric acid, by alkali and bromine; by hypochlorous acid and aqueous bromine, forming bromic acid and liberating chlorine; by bromine with oxide of gold, forming bromide and bromate of gold. The dry acid is unknown.

Prep. The liquid acid is prepared, 1, by precipitating bromate of baryta with an exact equivalent of sulphuric acid, and evaporating gently to a syrupy consistence. 2. Mix a hot solution of bromate of potassa with fluosilicic acid, filter after cooling, evaporate, and, after some days, filter through glass several times. This acid still contains silica.

Prop. Scarcely odorous; taste very acid, though not corrosive. It reddens litmus paper powerfully at first, and soon after destroys its color. By heating, one part of the acid is volatilized, and the other resolved into oxygen and bromine; at 212° it is wholly resolved into bromine and oxygen. It is not affected by nitric or sulphuric acids, except when the latter is highly concentrated, when the heat produced sets free bromine and oxygen. It is also decomposed by sulphurous acid, sulphuretted hydrogen, the hydracids of bromine, iodine, and chlorine, and their salts.

		In 100 pts.	Balard.
Br.....	78.4	66.21	64.69
5 O.....	40.0	33.79	35.31
BrO ₅	118.4	100	100

Bromates. They may be formed by direct union of the acid and metallic oxide; the alkaline bromates are made by adding bromine to caustic or carbonated alkali as long as the color disappears, or by dissolving chloride of bromine in a solution of alkali, and separating the bromate from bromide by crystallization, the former being more insoluble; the insoluble bromates are formed by double decomposition with bromated alkali and a metallic salt. The bromates are mostly soluble; their solutions precipitate the salts of mercurous oxide yellowish white and soluble in nitric acid, silver salts white, soluble in ammonia, not in dilute nitric acid, lead salts white, when very concentrated. They are decomposed by heat into oxygen and bromine, (KO , NaO , HgO , AgO), or bromine, oxygen, and metallic oxide (MgO , Al_2O_3 , ZnO); they deflagrate by a blow with sulphur, charcoal, &c.; they are decomposed phosphoric, sulphuric, sulphurous, nitric sul-

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pho-, bromo-, chlorohydric, oxalic, and acetic acids.

Chloride of Bromine. Formed by transmitting a current of chlorine through bromine, and condensing the disengaged vapors by means of a freezing mixture. It is a volatile fluid of a reddish-yellow color, of a penetrating odor, and causing a discharge of tears from the eyes; taste hot and very disagreeable. Vapor a deep yellow; metals burn in it, forming metallic chlorides and bromides.

Chloride of bromine is soluble in water; the solution possesses the color, odor, and bleaching properties of the dry chloride. By the action of the alkalis it is decomposed into a chloride and bromate. It congeals at -4° , and decomposes by sun-light into muriatic and bromic acids.

A hydrate of chloride of bromine is formed by passing chlorine into bromine covered with water or by cooling a mixture of chloride of bromine and water below 32° . It forms light yellow scales of the same odor and taste as the dry chloride, which fuse about 45° to a light yellow liquid, and are rapidly decomposed by ammonia into nitrogen, chloride of nitrogen, and bromide of ammonium.

Bromine combines farther with iodine, sulphur, selenium, nitrogen, phosphorus, carbon, boron, silicon, the metals, and some organic bodies.

BROMLITE. *Min.* Probably the same as *BARYTOCALCITE*. Found at Bromley Hill near Alston, whence the name.

BROMO or *BROM*. A prefix to some organic compounds containing bromine, which will be found under the radicals or substances with which it combines. Thus, *Bromobenzoic acid*, *Bromisatin*, &c., are given under *BENZYL*, *ISATIN*, &c.

BROMOFORM. See *FORMYL*.

BRONZE. *Tech.* An alloy of copper, with tin, zinc, &c. Two kinds may be distinguished, Antique and Modern Bronze, the former consisting of copper and tin, the latter containing zinc, in addition to copper and tin, or sometimes containing no tin. Modern bronze may therefore be brass with an excess of copper. The principal objects of bronze are cannon, bells, statues, and medals, the principles of manufacture in all being similar.

Manufacture of Cannon.

Cannon-metal consists of 9 or 10 pts. tin with 91 or 90 pts. copper. Other metals have been employed, but no alloy equals that just stated in all essential properties. Both the copper and tin should be of the best quality, containing neither lead, zinc, nor arsenic. The substance most generally preferred for the mould is a mixture of clay, sand, brick-dust, cow-hair, and horse-dung. Reverberatory furnaces are employed for fusing the alloy, either circular or oval, the former being heated with wood, the latter with coal, but the latter is sometimes objectionable from its content of sulphur (pyrites). The tin present in bronze being readily oxidized, a simple draft of air and no blast is employed for the combustion, and even the usual quantity of air entering a reverberatory should be diminished to what is essential for combus-

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tion only. Old bronze and copper are first introduced, the fire ignited, and slowly increased for several hours, the nearest portions fuse, and when after 6—7 hours the metal is at a white heat, it is nearly all fused, and the tin, with some copper, oozes out at all pores. When all is in fusion, the metal is stirred briskly with poles, which causes the escape of much gas with active ebullition, thereby mixing the lower and heavier portions with the upper and lighter, and producing greater uniformity of composition.

The liquid is skimmed of scoria and dross, more metal added, skimmed again, and the tin then added, portionwise, about an hour before casting, stirring the mass repeatedly, and increasing the heat. When the proper heat is attained, the metal is run off by a gutter into the mould, and, notwithstanding the high heat to which the mould had been subjected, the liquid metal develops much more gaseous matter. The escape of gaseous matter and other causes produce small openings in the mould, through which an alloy of tin and copper oozes out of greater fusibility, and consequently of slower congelation than bronze. After being fully cooled, the mould is taken apart and the piece bored.

Casting of Bells.

Bells should be composed of copper and tin alone, but it is usual to introduce zinc and lead, chiefly for the sake of economy. The proportions should be 78 copper to 22 tin, although a larger quantity of the latter is employed to allow for loss by oxidation, or a portion of it is replaced by zinc and lead; larger bells contain more copper than the smaller. The bell is cast upright, and the mould constructed in a pit; it is formed by a profile of wood revolving round the vertical axis of the mould. The furnace resembles that for cannon, but the temperature is lower, since the alloy is more fusible. The copper and two-thirds of the tin are first fused, and the remainder of the tin added a little before casting. The whole quantity of metal should be 10 per cent. more than the weight of the bell to be cast, to allow for loss by oxidation. The metal is run into the mould in the usual way.

Bronze Statues.

A rude outline of the figure is made of sand, loam, hair, &c., and is covered with a layer of wax, or rather a mixture of wax, turpentine, and fat, on the surface of which is modelled the exact representation of the figure in all its details. This is then covered with the outer case of the mould, which enters into the outlines of the figure, dried thoroughly, then heated to melt out the wax and harden the mould. The space which the wax occupied is to be filled with the melted bronze. The composition of bronze for statues is very variable, that of the ancients and of some moderns consisting of copper and tin, while the greater part of that of the moderns is composed of copper, zinc, and tin, or a species of brass with excess of copper.

Bronze Medals.

Medals and ancient coin are composed of copper and tin, being similar in composition to

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ancient statue-bronze. The metal should flow freely, fill all the lines of the mould, and have sufficient tenacity to resist the action of impression from the die. It is fused in crucibles, and cast in mould of a slightly argillaceous sand. The crucible containing some 8—10 lbs., should be fused in some 15 minutes, which is best attained by a blast of air, and when the melted metal is cooled down to the proper point, neither too hot to render the bronze vesicular by the escape of gas, nor too cool to flow sluggishly, it is poured into the moulds. As soon as the metal is solidified, it is taken out of the mould, still hot, and plunged into water to render it more malleable. The medal is then impressed by the die some 2—4 or more times, when it is bronzed. See below.

Properties of Bronze.

Taking bronze in a more limited sense, as consisting of copper and tin, it has the following general properties. It is harder and more fusible than copper; it is slightly malleable, when it contains over 85 per cent. copper, and becomes more so by tempering; it oxidizes very slowly in moist air. Its density is greater than the mean density of its constituents, as shown by the following table:

Alloy.		Observed density.	Calcul. density.	Difference.
Copper.	Tin.			
96.2	3.8	8.79	8.74	0.05
94.4	5.6	8.78	8.71	0.07
92.6	7.4	8.76	8.68	0.08
91.0	9.0	8.76	8.66	0.10
89.3	10.7	8.80	8.63	0.17
87.7	12.3	8.81	8.61	0.20
86.2	13.8	8.87	8.60	0.27
75	25	8.83	8.43	0.40
50	50	8.79	8.05	0.74

We might suppose from this, that the density increased with the proportion of tin, were it not for the vesicular structure bronze is apt to assume by fusion; it only proves that it becomes more homogeneous and compact. To determine the density of different bronzes would be important in the manufacture of cannon.

Oxidation. When bronze is fused in contact with air, both metals oxidize, but the tin more rapidly than the copper, thus, with 91 copper + 9 tin, one part of the latter oxidizes to only 2 or 3 of the former, leaving the alloy richer in copper, and of course equally altered in its properties. The following table of Dussaussoy illustrates this. The alloy was cannon metal, 90 copper + 10 tin, and the casting made in sand.

No. of fusions.	Wt. of Ingot in ounces.	Per ct. waste.	Spec. grav.	Composition,	
				Copper.	Tin.
1	268	1.2	8.565	90.4	9.6
2	236	1.6	8.460	90.7	9.3
3	204	2.1	8.386	91.7	8.3
4	172	2.5	8.478	92.8	7.2
5	140	2.6	8.529	93.7	6.3
6	104	3.0	8.500	95	5

The greatest inconvenience arising from refusion is the production of cavities and inter-

BRONZE.

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vening coats of oxide, which may be obviated, for example, by fusing ingots 5 or 6 in contact with charcoal, adding sufficient tin to bring up the alloy to the original composition, when it produces a very fine metal without cavities.

It is in consequence of this tendency to oxidize that the fusion, except for cannon, should take place as rapidly as practicable, that a large proportion of tin is added just before casting, that the flame and furnace should contain as little free oxygen as possible, and that many foundries cover their melted metal with fine charcoal or coke.

In cooling pure bronze in moulds of sand, there is usually observed a jet of metal a few moments after casting, which appears either in the crevices of the mould or rises to the free surface of the metal, urged out by the escape of gas. This metal is an alloy usually con-

taining 19 per cent. tin, and its appearance proves that the least fusible atomic alloy crystallizing first contracts the mass, and the pressure of the metallic column forces the still fluid alloy either to the circumference or towards the top; hence towards the lower part and centre of the casting, the alloy is richer in copper, towards the circumference and in every portion of the top it is richer in tin, as has been shown by analysis.

Tempering. By heating bronze and plunging it in cold water, it becomes less dense and hard, more malleable, so that it may be hammered, more flexible, and sometimes more tenacious; its color and granular texture are also changed, and the tone or ring of the metal becomes more grave. Dussaussoy obtained the following results with different alloys, before and after tempering:

Alloy.		Density.		Hardness.		Tenacity. ½ line thick.		Tenacity. 8 lines thick.	
Copper.	Tin.	Before.	After.	Before.	After.	Before.	After.	Before.	After.
95	5	7.92	7.89	100	99	80	100	100	75
90	10	8.08	8.00	100	98	66	100	100	78
85	15	8.46	8.35	100	96	48	100	80	100
80	20	8.67	8.52	100	92	50	100	80	100
75	25	8.57	8.31	100	91	70	100	100	35

It appears, therefore, that the alloy composed of 80—85 copper + 20—15 tin, or about 8 eq. to 1 equiv., Cu_8Sn , is best adapted to tempering, and gains in tenacity when of different thicknesses. Hence, such pieces may be tempered, then hammered, turned or impressed, and again hardened by reheating.

Composition of Bronze.

The composition of different kinds of bronze is presented at p. 121, under *ALLOY*. The larger the quantity of tin or white metals, the whiter the color of the bronze, and, in general, the more brittle and fusible. Cannon metal of 90—91 per cent. (= 16 or 18 eq.) copper to 10—9 per cent. (= 1 eq.) tin (Cu_{18}Sn) has a reddish tint, is very hard and tough, powerfully resisting abrasion and the chemical action of atmospheric agents more than brass. The alloy for cymbals or gongs, of 81 per cent. copper + 19 tin (Cu_8Sn), has an orange-white tint, and is best adapted to tempering. An alloy of 76.0 per cent. copper + 24 tin (Cu_8Sn) is slightly orange-white, very brilliant, brittle, with a somewhat conchoidal fracture, with traces of crystallization. Speculum metal composed of 66½ copper + 33½ tin (Cu_4Sn) has a steel-white lustre, is very brilliant, brittle, has an uneven fracture, and takes a high polish.

The addition of about 1 per cent. of iron, or rather of common tinned iron (sheet-tin), is found to make a harder and more tenacious bronze, for small objects, but appears to be of little benefit to objects of larger size. Larger quantities of zinc may be added to bronze with the same results, as is often done in statue-bronze, bells, &c. A small quantity of lead may be added, but it rather diminishes the valuable properties of bronze, rendering it more susceptible to oxidation, and tending to separate towards the bottom of a large casting.

The proportion of metals for *cannon* may vary with the dimensions of the piece, the smaller containing 8 per cent., and the larger 9—10 per cent. tin. The alloy for *bells* is very variable; the best proportion for tone is 22 per cent. tin; but zinc and lead are substituted for a portion of the tin for the sake of economy. The lead is decidedly injurious to the tone. *Speculum metal* is, in general, composed of 66 copper and 33 tin, but brass and arsenic are also added. The addition of zinc for medals and statues enables them to assume better the color characteristic of antique bronze.

Bronzing.

When bronze is exposed for a great length of time to atmospheric agents it assumes a peculiar greenish or olive hue, arising from the formation of a basic hydrated and carbonated oxide of copper, or a dark olive hue from sulphuret of copper. Being an attractive color, numerous experiments have been instituted to discover a method of attaining the same result in a short time. It is usually effected by means of a salt of copper, mixed with other salts, dissolved in water or weak acids, and applied to the surface with a brush, or the objects are immersed in the solution. 2 pts. verdigris and 1 pt. sal-ammoniac are dissolved in vinegar, boiled, filtered, and much diluted, and the medals, &c., immersed in the solution until they acquire the desired color, when they are washed. Binocalate and bitartrate of potassa are employed with sulphate, nitrate, or acetate of copper. After attaining the bronze-color, the objects should be thoroughly washed in pure water, with repeated washings, to remove every trace of salts or acids, and thereby prevent the surface from farther change.

Different tints may be imparted to bronze, from a reddish to a light yellow, by acting upon

it with acids and salts, by which either copper or zinc may be extracted. Thus, boiling muriatic acid extracts a considerable quantity of tin before attacking the copper. Mixtures of saltpeter, common salt, and sulphuric acid may be made to extract either copper or the white metals, and thus the color may be varied.

Tinning Copper.

This depends upon the affinity of copper and tin, whereby a small quantity of the latter is fixed upon the surface of the former. The important principle in tinning is that the surface of the copper be clean and perfectly free from oxide, and be so maintained during the process. This is attained either by the use of sal-ammoniac or resin, with melted tin, or by cream of tartar in solution and grained tin.

The sal-ammoniac is either dissolved and brushed over the surface of the copper, or it is heated and its vapor condensed on the surface; tin is then introduced, melted, and rubbed over the surface with tow. The process with resin is conducted in a similar manner. Tinning with sal-ammoniac is more durable, but requires the use of nearly pure tin; tinning with resin allows the employment of an alloy of lead and tin. The quantity of lead should never exceed $\frac{1}{8}$ or $\frac{1}{10}$ of the tin, as it might otherwise prove detrimental to those employing food prepared in such vessels.

Tinned vessels, whether containing lead or not, are not to be recommended in place of good bell-metal, certainly not for the preparation of food, especially if the latter be acid, or the vessel is to be heated.

Whitening Pins. Copper or brass is easily tinned in the wet way. Thus, in the pin manufacture, when they are completely formed, they are cleansed in a pickle of sulphuric acid, vinegar, cream of tartar, &c. They are then thrown into a copper vessel, stratified with grained tin, covered with water, cream of tartar added, and the whole boiled. The cream of tartar probably acts by dissolving a portion of tin, and then transferring it to the pins, which, containing zinc, become electric by contact with tin.

On Bronze designed for gilding, consult D'Arcet, *Essay*, Paris, 1818, also *Dict. Technologique*, t. iii. p. 507. On Cannon Metal and bronzes, see Dussaussoy *An. de Ch. et de Phys.* t. v. p. 113 and 225; Gay-Lussac, ditto, t. vii. p. 389; Lenarmont *An. des Mines*, ser. iii. t. iii. p. 231; ditto, p. 93—258; Karsten, *Schw. Journ.* Bd. v. 387; Meyer, *Erd. Journ.* vii. 394; xviii. p. 1, &c. On Bronze Medals by Puymaurin, Paris, 1824, by Chaudet, *An. de Ch. et de Phys.* vi. 46. On Speculum Metal, Gill's *Techn. Repository*, i. 240; *Journ. Frank. Inst.* vol. ii.

BRONZING. *Tech.* Two kinds of bronzing may be distinguished, 1st, where a bronze hue is communicated to brass, bronze, &c., by a chemical action on the surface, and, 2d, where a pigment is applied to any surface in imitation of bronze. The latter is referred to in the present article; the former is described under **BRONZE**.

Imitation of Bronze. The pigments and varnishes are applied to the surface of wood, plaster, &c. The objects to be bronzed are first

covered over smoothly with a coat of size or oil-varnish, and when nearly dry, the metallic powder made from Dutch foil, gold leaf, mosaic gold, or precipitated copper, is applied with a dusting-bag, and then rubbed over the surface with a linen pad; or the metallic powders may be mixed with the drying oil beforehand, and then applied with a brush. Sometimes fine copper, or brass-filings, or mosaic gold, are mixed previously with some pulverized bone-ash, and then applied in either way. A mixture of these powders with mucilage of gum arabic is used to give paper or wood a bronze appearance. The surface must be afterwards burnished. Copper power precipitated by clean plates of iron, from a solution of sulphate or nitrate of copper, after being well washed and dried, has been employed in this way, either alone or mixed with pulverized bone-ash. A finish is given to works of this nature by a coat of spirit-varnish. The iron-coloured bronzing is given by black lead or plumbago, finely pulverized and washed.

Statues and various objects in plaster may be bronzed in the following manner. To a solution of soda-soap with linseed oil, cleared by straining, add a mixed solution of 4 pts. blue vitriol and 1 pt. copperas, which precipitates a mixed cupreous and ferruginous soap. Wash them with cold water, strain and dry them. The former being green, and the latter brownish, they give a peculiar bronze hue. The dry powders are thus applied:

Three pounds of pure linseed oil are to be boiled with twelve ounces of finely-powdered litharge, then strained through a coarse canvas cloth, and allowed to stand in a warm place till the soap turns clear. Fifteen ounces of this soap-varnish, mixed with 12 ounces of the above metallic soaps, and 5 ounces of fine white wax, are to be melted together at a gentle heat in a porcelain basin, by means of a water-bath. The mixture must be kept for some time in a melted state, to expel any moisture which it may contain. It must be then applied, by means of a painter's brush, to the surface of the gypsum previously heated to the temperature of about 200°F. By skilful management of the heat, the color may be evenly and smoothly laid on without filling up the minute lineaments of the busts. When, after remaining in the cool air for a few days, the smell of the pigment has gone off, the surface is to be rubbed with cotton wool, or a fine linen rag, and variegated with a few streaks of metal powder or shell gold. Small objects may be dipped in the melted mixture, and then exposed to the heat of a fire till they are thoroughly penetrated and evenly coated with it. *Ure*.

A good method to bronze wood is to grind separately prussian blue, chrome yellow, raw umber, lamp-black, and clay, and add such proportions of each as will produce a desired dark green hue, to moderately strong size. The clean wood is first coated with size and lamp-black, then with the above color twice applied, and lastly with any of the above metallic bronze powders, Dutch foil, mosaic gold, &c., laid on with a pencil. Finish by a thin solution of Castile soap, and rub with a woollen cloth.

BRONZITE.

BRONZITE. *Min.* See **AUGITE**.

BROOKITE. *Min. Syn.* Prismatic Titanium ore, *Haid.* Jurinite, *Soret*.

Descrip. Cryst. System, Right Rhombic; the vert. prism = 100° and 80° , parallel to which it cleaves imperfectly. $H. = 5.5-6$. Color hair-brown, passing into orange; lustre brilliant, metallic-adamantine; translucent, opaque; brittle with light yellowish streak. *Compos.* In behavior and composition it is said to resemble Rutile, but has not been analyzed. An analysis would be extremely interesting by comparison with Rutile and Anatase, which belong to the quadratic system, and yet are both said to be titanite acid. *Local.* Dauphiné; Snowden, Wales; Phenixville, Philadelphia, *J. A. Clay*.

BROWN COAL. See **COAL**.

BROWN HEMATITE. *Min. Syn.* Prismatic iron ore, *M.* Hydrous Peroxide of Iron, Brown Ochre, Brown Iron-stone, Bog-ore, Pipe-ore; *Ger.* Brauneisenstein, Brauner Glaskopf, Thoneisenstein; *Lepidokrokit*, *Nadeleisenerz*; *Pyrosiderite*, *Göthite*, *Rubinglimmer*; *Stilpnosiderite*, *Pecheisenerz*.

Descrip. There are two classes, see *analysis* below, differing slightly in external characters and composition. The 1st occurs in imitative forms, with a fibrous structure, and, when mixed with clay, compact. $H. = 5-5.5$. $G. = 3.5-4$. Color deep brown, with a lighter brown streak, when earthy yellowish brown; lustre silky; jet black and shining on the mamillary planes terminating the fibres; opaque; brittle; bog-ore is compact, with a resinous lustre; pipe-ore usually dull and glimmering, and of a stalactitic form.

The 2d class is sometimes crystallized, and appears to be Right Rhombic; $H. = 3-5$. $G. = 3.6-4.2$; color brown and nearly black; lustre sub-adamantine; often blood-red by transmitted light; streak brownish orange and ochrey.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Sesquioxide of iron	90.53	85.65	86.35	86.24	86.34	86.32	86.87	90.02	76.8
Water	9.47	11.50	11.38	10.68	11.66	10.80	11.13	10.19	10.0
Sesquiox. of mang.	—	2.50	0.51	—	—	—	—	—	8.2
Silica	—	0.35	0.85	2.00	2.00	2.88	2.00	—	4.3
	100	100	99.09	98.92	100	100	100	100.21	99.3

No. 3 contained also 0.90 of oxide of copper, and No. 4, 1.08 of phosphoric acid. These, by calculation, lead to the formula, $Fe_2O_3 + HO$, containing 89.47 per cent. oxide of iron, and 10.53 per cent. water. Breithaupt and Kersten insist that *Lepidokrokit* belongs to the first class, as they found it to contain 13 per cent. water. There are numerous other localities beside the above. See farther under **IRON ORES**.

BROWN SPAR. *Min.* See **SPARRY IRON**.

BRUCITE. *Min.* See **CHONDRODITE** and **HYDROUS MAGNESIA**.

BRUCIN. *Phar.* (After Brucea, brought by Bruce from Abyssinia.) Discovered by Pelletier and Caventou, in 1819, in the bark of the *Brucea antidysenterica*, and afterwards detected with strychnin in *Nux vomica*.

Prep. 1. The bark reduced to a coarse powder, is digested in ether to remove the greatest part

BRUCIN.

Behavior. They yield water in a closed tube, becoming peroxide of iron with a red streak; thin splinters of the fibrous varieties sometimes fuse on the edges to a black magnetic glass. In other respects they behave as peroxide of iron, often giving traces of manganese. They are all soluble by digestion in strong chlorohydric acid, the impure often leaving silica.

Analysis. The varying results of different analysis lead to the supposition that there are several hydrates of the peroxide of iron, two of which are well established. Of the 1st class, including the ordinary fibrous brown hematites, 1, from Viedessos, was analyzed by D'Aubuisson; 2, from Welsdruff, by Kersten; 3, from Braunschweig, by Rammelsberg.

	1.	2.	3.
Sesquioxide of iron	82	62.93	80.76
“ “ manganese	2	—	—
Water	14	10.41	12.71
Silica	1	22.20	4.58
Alumina	—	1.84	2.63
	99	97.38	100.68

The 2d contains in addition 1.33 phosphoric acid, and the 3d 0.92 of lime. By calculating these 3 as pure hydrated oxides, and omitting the others as not essential, we have nearly the proportions for sesquihydrate of the peroxide, with 86.95 per cent. peroxide + 13.05 per cent. water. Its formula is therefore $2Fe_2O_3 + 3HO$.

Of the second class. 1, *Lepidokrokit* from Oberkirchen in Westerwald, 2, from Hollerter Zug, both by V. Kobell; 3, *Göthite* from Eisfeld in Siegen; 4, *Stilpnosiderite* from Amberg in Bavaria; 5, compact brown iron-ore from Saxony, 6, from Maryland, 7, from Beresow, 3—7 by Brandes; 8, ditto from Sterlitamak by Herrmann; 9, compact red hematite from Aroostook river, Maine, by C. T. Jackson.

of the fatty matter, then in strong alcohol. The alcoholic solutions are distilled in a water-bath to drive off the alcohol, the residual matter dissolved in water, and the solution mixed with subacetate of lead to throw down the coloring matter, and the excess of lead removed by a current of sulphuretted hydrogen gas. The brucin is then thrown down by boiling with magnesia, and the liquid evaporated, when a brown granular alkaline mass is obtained, which is saturated with oxalic acid, and the oxalate washed with absolute alcohol, at the temperature of 32° . The oxalate of brucin is decomposed by boiling with magnesia and water, the brucin dissolved in boiling alcohol and obtained in crystals when the solution cools. *Pell. and Cav.*

2. Digest the bark in water, add oxalic acid to the decoctions, evaporate the liquid to the

consistence of an extract, and digest this extract in alcohol at 32°; oxalate of brucin remains, which is treated in the way just described. *Thenard*.

3. The brucin remaining in the washings of strychnin may be thus extracted: Evaporate the liquid to the consistence of a syrup, and add dilute sulphuric acid, very little beyond saturation. In two or three days abundance of crystals will be formed. These are put into a cloth and exposed to strong pressure, and then washed in a little cold water, dissolved in boiling water, the solution treated with animal charcoal, and filtered. Ammonia throws down pure brucin from this liquid. *Corriol*. See **STRYCHNIN**.

Prop. From a dilute alcoholic solution it crystallizes spontaneously in colorless, transparent, oblique 4-sided prisms, by rapid evaporation in pearly scales. The crystals contain 15.5 or 16.5 per cent. water, which they lose at a little above 212°. Fused brucin is an amorphous, waxy mass, which resumes its hydrated character in a few days, when moistened. When its salts are precipitated by caustic alkali, it separates as anhydrous brucin in the form of a tough, pasty mass, which swells in pure water resuming its hydrate-water. When heated above its point of fusion it yields combustible gases, little carbonic acid, water, empyreumatic oil, and no ammonia.

It is soluble in 850 cold, 500 boiling water, and more soluble in proportion to the extractive matters present; very soluble in alcohol, even dilute, not in ether or fat oils, slightly in essential oils. Its solutions are very bitter.

The alkaloid or its salts is decomposed by chlorine, becoming yellow, then dark red, finally yellow; and by saturating the generated chlorohydric acid with ammonia, a shining white substance is obtained, of bitter taste, soluble in alcohol, not crystallizable, not poisonous. Tincture of iodine, not in excess, added to an alcoholic solution of brucin, precipitates an orange-brown powder.

Its action with nitric acid is characteristic. It produces a bright red solution, which is decolorized by sulphuretted hydrogen, sulphurous acid, or protochloride of tin. By warming the solution, or by more nitric acid, the red color becomes yellow, and tin salt produces a brilliant violet color and precipitate. By this test it may be distinguished from strychnin and morphin.

Brucin resembles strychnin in its poisonous action, but is far less energetic.

Form. $C_{44}H_{25}N_2O_7$, or $C_{48}H_{26}N_2O_8$. *Sym.* Br.

Salts. The salts of brucin are neutral and acid; their taste is bitter, and most of them crystallizable; decomposed by the alkalies, and by morphin and strychnin, which throw down the brucin.

Muriate of Brucin. Neutral, crystallizing in 4-sided prisms, frequently in fine needles; not altered by exposure to the air; very soluble in water; when heated to the point at which the alkaloid begins to decompose, the acid escapes.

Hydriodate of B. Obtained by dissolving brucin and iodine in water, transparent, rectangular prisms, soluble in cold, very soluble

in hot water, more soluble in alcohol than in water.

Sulphate of B. The neutral salt crystallizes in long slender needles, is very soluble in water, and slightly in alcohol, taste intensely bitter.

+ $BrSO_3$, 8 HO. Exposed to the air it effloresces, losing two atoms water.

The *Bisulphate of Brucin* is formed by adding a little water to a solution of the neutral sulphate; ether removes any excess of acid, and leaves the bisalt. It crystallizes readily.

Nitrate of B. Obtained by dissolving brucin in very dilute acid; it does not crystallize, but when evaporated becomes a gummy mass.

+ $Br, NO_5 + 5 HO$.

The *bimuriate* crystallizes in 4-sided prisms, with bihedral summits. When heated, it becomes red, then blackens and enflames.

Phosphate of B. The neutral salt does not crystallize. The *biphosphate* crystallizes in rectangular tables with bevelled edges, efflorescent, is very soluble in water, scarcely in absolute alcohol.

Chlorate of B. When dilute chloric acid is heated with brucina, it assumes a red color, but crystallizes, on cooling, in transparent, regular rhomboids, which become colorless by a second crystallization.

Iodate of B. Brucin combines with iodic acid; the solution is colorless, if neutral. By evaporation and rest, two salts are obtained from it: the subsalt opaque and silky, the acid transparent, hard, and in 4-sided prisms.

Oxalate of B. Crystallizes in long needles, especially with an excess of acid; is very soluble in absolute alcohol.

Acetate of B. Is very soluble in water, and not crystallizable.

Brucin is also precipitated by tannic acid.

BRUNOLIC ACID. *Chem.* An acid obtained by Runge by the distillation and farther treatment of coal-tar. It is separated with difficulty from rosolic acid. It is a brown, shining mass resembling asphalt, and its salts are brown and generally insoluble. See *Dry Distillation of Coal*.

BRUNSWICK GREEN. *Tech.* An oxychloride of COPPER.

BRYONIN. *Phar.* From the root of *Bryonia alba*. According to Brandes and Firnhaber, the root is composed of

Bryonin, with a little sugar	1.9
Resin, with a little wax	2.1
Soft resin	1.3
Molasses sugar	10.0
Gum	14.9
Starch	2.0
Pectic acid	2.5
Amylaceous fibre	1.0
Coagulated albumen	6.2
Mucilage	0.27
Extractive	1.7
Phosphates of magnesia and alumina	0.5
Malate of magnesia	1.0
Fibre	15.25
Water	20.0

BUCHOLZITE.

Prep. Bryonin is thus obtained by Brandes and Pirnhaber. The filtered juice is raised to boiling, filtered again, mixed with subacetate of lead, the precipitate washed and decomposed by sulphuretted hydrogen, the solution evaporated to dryness, and the dry residue being digested in alcohol, bryonin is dissolved.

Prop. It is a yellowish-brown extract-like substance, with an exceedingly bitter taste, soluble in water, more soluble in alcohol when dilute than when anhydrous, insoluble in ether, has neither acid nor alkaline properties, is not crystallizable. Chlorine does not act upon it; strong sulphuric acid dissolves it, assuming first a blue and then a deep green color. Nitric acid dissolves it, forming a liquid, at first brown, but becoming speedily yellow, from which water throws down a light yellow precipitate; by evaporating the solution to dryness a yellow resin remains. Muriatic acid also dissolves it. Caustic alkalies dissolve bryonin without alteration. Its aqueous solution is not precipitated by acetate or nitrate of lead, protochloride of tin, tartar emetic, nor by the salts of zinc, iron, or copper; but it is precipitated white by nitrate of silver, yellow by chloride of gold, and abundantly by nitrate of mercury and subacetate of lead. The infusion of nutgalls throws down a copious gray precipitate, difficultly soluble in water, more readily in alcohol.

BUCHOLZITE. *Min.* Syn. Fibrolite, Xenolite. *Nord.* Cryst. system, Hexagonal(?) Imperfectly crystalline, fibrous; a crystal of Xenolite was a 3-sided prism with two angles of $45^{\circ} 38'$, and one of about 90° .

H. = 6—7. G. = 3.193; of Xenolite, 3.58. Color white, or gray, inclining to yellow, lustre pearly, waxy, and glistening; streak white; thin fragments translucent, subtranslucent; fracture conchoidal across the fibres; brittle.

Behavior and Analysis. It is infusible before the blowpipe and not attacked by acids. 1. From Faltigl, in Tyrol, by Brandes; 2, from Chester, Delaware county, Pennsylvania, by Thomson; 3, Xenolite, from Petershoff, in Finland, by Komonen.

	1.	2.	3.
Silica	46.0	46.40	47.44
Alumina	50.0	52.92	52.54
Oxide of iron....	2.5	trace	—
Potassa	1.5	—	—
	100	99.32	99.98

Hence its form. is Al_2O_3, SiO_3 , which agrees closely with the 3d.

Local. Originally obtained from Fassa, in Tyrol; since discovered at Chester, Pennsylvania, in Monroe, Orange county, New York, at Humphreysville, Connecticut, and at Worcester, Massachusetts.

The Xenolite of Nordenskiöld is shown to be identical with this species by Teschemacher. It was found in boulders in the province of Petershoff in Finland. *Dana.*

BUCHU. *Phar.* The leaves of several species of *Barosma* (*Diosma*). The following analyses of the leaves of *Barosma crenata* are, 1, by Brandes, 2, by Cadet:

BUTTER.

	1.	2.
Pale yellow volatile oil.....	0.88	0.665
Resin	2.34	2.151
Bitter extractive (<i>Diosmin</i>)	3.78	5.170
Chlorophyll	4.77	1.100
Gum.....	12.71	21.170
Lignin.....	45.00	
Brown substance extracted by potash	1.56	
Nitrogenous matter extracted by potash	2.42	
Albumen.....	0.58	
Malic acid, and matter precipi- table by tannin	1.56	69.744
Bassorin, with oxalate and phos- phate of lime.....	4.53	
Various salts of potash and lime	3.07	
Water.....	12.94	
Acetic acid and loss	3.86	

The volatile oil is yellowish brown, lighter than water; odor that of the leaves. The bitter extractive is brownish yellow, bitter, and somewhat pungent; soluble in water, but neither in alcohol nor ether.

BUCKWHEAT. The seed of *Polygonum fagopyrum*. The seed dried in the sun contains, according to Zenneck:

Resin.....	0.3636
Gluten.....	10.4734
Albumen.....	0.2272
Apothem.....	2.5378
Saccharine extractive.....	3.0866
Mucilage and gum.....	2.8030
Starch.....	52.2954
Fibre.....	26.9341
Loss.....	1.2500

BUCKLANDITE. *Min.* See **EPIDOTE**.

BUSTAMITE. *Min.* Syn. H. = 6.5. G. = 3.1—3.23. Prismatic, fibrous; color pale gray, greenish or reddish; lustre a little silky, but weak; subtranslucent.

Analysis by Dumas:

Silica.....	48.90
Protoxide of manganese.....	36.06
Lime	14.57
Protoxide of iron	0.81
	100.34

Its formula is $3 CaO, 2 SiO_3 + 2 (3 MnO, 2 SiO_3)$, or the general form. $3 RO, 2 SiO_3$. It is allied to augite and manganese spar.

Local. Discovered in Mexico, at Real de Minas de Fetela, and at Inotlæ in the province of Puebla.

BUTTER. *Ger.* Butter; *Fr.* Beurre. A fat obtained from the milk of the cow by a strong and constant agitation of cream, which promotes the separation or collection of the particles of fat. It is a soft, yellowish or reddish white fat of a peculiar, agreeable taste and odor, due to salts of volatile acids. It usually contains a little butter-milk, &c., from which it is purified by melting several times in hot water. It consists of margarin, butyrolein, butyryn, caprone, capryllin, and caprin, and sometimes vaccinin instead of butyryn and caprone; the five last are compounds of oxide of glyceryl, with the volatile fat acids, viz. butyric, caproic,

caprylic, capric and vaccinic, (*Lerch*); the two first contain margaric and butyrolic acids. It also contains coloring and aromatic substances. (Refer to the above acids.)

The proportions of the ingredients in butter were approximately determined by Bromeis to be:

Margarin.....	68
Butyrolein.....	30
All others	2
	100

The apparatus in which cream is *churned* or agitated may be of wood, iron, or sheet-tin; the first is preferable, but it should contain no essential oil or odorous matter whatever; it should be rounded and have as few corners as possible, in order to facilitate its cleansing, and should be kept as clean as possible. The agitation should be neither too rapid nor too slow; the lower the temperature, the more rapid. The temperature should be as near 55° as practicable; if above 60°, there is a loss in quantity and quality; if below 50°, the operation becomes too long; but churning raises the temperature several degrees. When the butter has collected (*come*), it is removed, and worked with fresh and pure water to remove the adhering butter-milk, but too much working lessens the flavor, while it improves its quality for keeping. There is no doubt that the quality of the water has some influence on the quality of the butter.

For keeping, butter may be either salted with common salt, which contains no deliquescent salts, or covered with syrup. When not well prepared, it is very apt to become rancid, from the presence of caseous fermentative matter. This may be removed from fresh butter, either by melting alone at 190° to 212°, when the caseous matter partly rises to the surface, partly sinks to the bottom, or by melting it several times with water.

BUTTER of ANTIMONY, BISMUTH, TIN, ZINC, is a chloride of the metal.

BUTTER is applied to several vegetable fats, which have the consistency of common butter, such as butter of CACAO, COCOA, NUTMEGS, &c.

BUTYRIC ACID. *Chem. Ger.* Buttersäure. The volatile acids of butter are thus obtained:

Fresh butter is completely saponified with potassa in a still, the soap decomposed in the vessel with dilute sulphuric acid, the head then luted on, and the aqueous liquid drawn off to within a fourth. Fresh water is added, again distilled off, and this operation continued as long as the water which passes over possesses any acid reaction from the volatile acids. From 4 to 5 pints of a milky liquid are obtained from a pound of butter, on the surface of which float drops of oil and particles of hard or smeary fat. The distilled water is immediately saturated in the receiver with barytic water, and allowed to stand well-closed till the end of the distillation. When the distillation is finished, the still is cleansed and the liquid saturated with barytic water, evaporated in it with the head on to about the twentieth part, and the still-hot concentrated ley then reduced to dryness in a retort.

The saline mass obtained in this manner consists of two portions, one easy of solution, the other difficult. The more soluble portion consists, according to circumstances, of butyrate and caproate of baryta, or solely of the barytic salt of vaccinic acid. The portion difficult of solution consists of the baryta salts of capric and caprylic acids. To separate the different salts, the residuary saline mass is boiled with about 5 to 6 pts. water; one portion dissolves, the other remains behind. The solution of the easy soluble salts is set aside to crystallize; if, on the first crystallization, the crystals which separate do not effloresce, they are caproate of baryta, and the butyrate of baryta is still in the solution; but if nests of small crystals form, which quickly effloresce, it is vaccinate of baryta, and it is then unnecessary to look for butyrate and caproate of baryta.

The soluble saline mass, containing the butyric and caproic acids, is dissolved in water and evaporated to crystallization; and if the solution has been sufficiently concentrated, nearly the whole of the caproate salt is deposited. The entire solution solidifies to a paste of minute needles, which are separated by pressure from the mother-ley and purified by recrystallization. The remaining ley is now allowed to crystallize spontaneously, which is best effected by exposure to the sun; at first a little caproate of baryta still separates, the form of the crystal then changes, laminæ of mother-of-pearl lustre make their appearance, and all the subsequent crystallizations are nearly pure butyrate of baryta, which is purified by recrystallization.

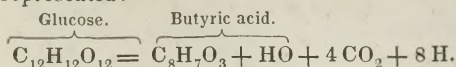
The saline mass of difficult solution is dissolved in just so much boiling water as is requisite for complete solution, and is filtered while hot. During the cooling the liquid becomes filled with minute scales, of a fatty lustre, of caprate of baryta, which subside in the form of a crystalline precipitate. The decanted mother-ley is again evaporated one-fourth, when a fresh quantity of caprate of baryta separates. This salt is purified by recrystallization. The mother-ley now contains the capryllate in solution; it is evaporated by exposure to the sun, when the salt separates in minute granules and verrucous masses, which are obtained pure by recrystallization. *Lerch.*

Butyric acid. Besides its occurrence in butter, butyric acid has latterly been observed to form under peculiar circumstances. It is among the constituents of tobacco-smoke (*Zeise*); it resulted from the fermentation of tartrate of ammonia (*Nöllner, Berzelius*); from the fermentation of potatoes (*Scharling*); from a peculiar fermentation of sugar (*Pelouze and Gelis*). The last offers a method of obtaining it, and it is as follows:

A small quantity of caseine is mixed with a solution of sugar and sufficient chalk to saturate the whole of the butyric acid which subsequently forms. This mixture is left at a constant temperature of 77° to 86°; the fermentation, at first viscous, subsequently lactic, gradually becomes butyric; the decompositions are sometimes successive, sometimes simultaneous. At one part of the fermentation free hydrogen amounts to a third of the volume of

BUTYRIC ACID.

the carbonic acid. At this period the butyric fermentation is in all its vigor; and at the end of some weeks the solution contains little else than butyrate of lime. The butyric fermentation of simple hydrated grape-sugar is thus represented:



The acid is thus extracted from butyrate of lime:

1 lb. butyrate of lime is suspended in 3 to 4 lbs. of water, to which have been added 5 or 6 ozs. of commercial hydrochloric acid. This mixture is introduced into a still, and boiled until about 1 lb. of distilled liquid has been obtained. It is placed in contact with chloride of calcium, which forms two liquids of different density, the upper stratum is butyric acid; it is removed, and submitted to distillation in a tubulated retort provided with a thermometer. The first portions which pass over into the recipient are more or less aqueous; the boiling point, at first very low, gradually rises to 327° , where it remains nearly stationary, and is a sign that the acid which distils over is concentrated; it is received apart, continuing the distillation until the retort contains but a small residue. The acid is now kept for some time at its boiling point, to deprive it of some traces of hydrochloric acid, and is then redistilled, when it is obtained perfectly pure.

The acid is obtained from butyrate of baryta by sulphuric or phosphoric acid, adding a little less than is sufficient for the decomposition of the salt.

Prop. Colorless, transparent oily liquid of great fluidity, of an odor resembling acetic acid and rancid butter; of a sharp acid taste, whitening the tongue; density = 0.963 at 59° ; is soluble in every proportion in water, alcohol, wood-spirit, ether, volatile and fixed oils, &c. It boils at about 327° under ordinary pressure, and distills without alteration; its vapor is inflammable, and burns with a blue flame.

Concentrated sulphuric acid has no effect on butyric acid at the ordinary temperature, and even when distilled with it the greater portion of the butyric acid distils over. A few drops let fall into dry chlorine immediately produces hydrochloric acid, and crystals of oxalic acid cover the sides of the flask.

Composition. Chevreul gave as the formula, $\text{C}_8\text{H}_{5\frac{1}{2}}\text{O}_3$, for which Berzelius proposed $\text{C}_8\text{H}_5\text{O}_3$. Bromeis gave $\text{C}_8\text{H}_6\text{O}_3$, but the analyses of Pelouze and Gelis, and Lerch lead to the formula for the hydrated acid, $\text{C}_8\text{H}_7\text{O}_3 + \text{HO}$, which is probably correct.

Salts. The salts are generally soluble, have the odor of butyric acid when moist, and especially on the addition of sulphuric acid; and some of them yield BUTYRONE by distillation. The butyrates of *potassa*, *soda*, and *ammonia*, are deliquescent and difficult to crystallize; that of baryta crystallizes in prisms or pearly laminae, with 4 eq. crystal-water, (*Pel. and Gel.*), anhydrous (*Lerch*), it produces the same motions as camphor on water; B. of *lime* is more soluble in cold than hot water, crystallizing by boiling a cold solution; there is a double salt of lime and baryta; B. of *magnesia* crystallizes in pearly

BUTYRONE.

scales, like boracic acid; with 5 eq. crystal-water. The salt of *zinc* crystallizes, and easily becomes basic by loss of acid; that of *iron* is yellow and basic; that of *copper* is bluish-green, crystallizable, and has the form. $\text{CuO}, \text{C}_8\text{H}_7\text{O}_3 + 2\text{HO}$; those of *lead* and *silver* are white precipitates, the former remaining as a dense liquid for some time, when butyric acid is added to acetate of lead. Butyrate of *ethyl* is obtained by boiling butyrate of baryta with alcohol and sulphuric acid, or rapidly in the cold by 2 butyric acid, 2 alcohol, and 1 sulphuric acid; it has an agreeable odor, is very fluid and inflammable, very soluble in alcohol and wood-spirit, slightly in water, boils at $220-230^{\circ}$; form. $\text{C}_4\text{H}_5\text{O} + \text{C}_8\text{H}_7\text{O}_3$. B. of methyl similarly formed from wood-spirit is analogous to the preceding, and has the composition, $\text{C}_2\text{H}_3\text{O} + \text{C}_8\text{H}_7\text{O}_3$.

BUTYROLEIC ACID. When butter is kept for some time at the temperature of 60° , the margarin congeals into white, solid groups of globules, and may be separated from the olein, &c., by pressure. *Prép.* The expressed oil is saponified with potassa, decomposed by dilute sulphuric acid, and the oily acids are separated and repeatedly boiled with water to separate the volatile acids. The butyroleic acid is then combined with litharge, dissolved in ether, in which the margarate of lead is insoluble; the lead-salt decomposed by chlorohydric acid, the acid dissolved in 10—12 pts. spirit of wine, passed through blood-charcoal to decolorize it, and dried in the cold over fused chloride of calcium. The employment of heat must be avoided since the acid absorbs oxygen with avidity. It is a colorless, oily liquid; spec. grav. 0.904. Formula, $\text{C}_{34}\text{H}_{30}\text{O}_4 + \text{HO}$.

The *soda*-salt is prepared by saponifying the acid with carbonate of soda, dissolving in absolute alcohol, and pressing; the alcoholic solution cools to a translucent mass, not crystalline. The *barytic* salt, prepared by adding chloride of barium to the pure salt of soda, is white, loose, contracts by heat, fusing to a clear, yellowish and brittle mass. The salts of lead and copper are very adhesive; the silver-salt decomposes in drying even in vacuo. Butyroleic ether, formed by dissolving 1 pt. pure acid in 4 or 5 pts. of warm absolute alcohol, and passing dry chlorohydric acid through it, is first boiled with water, then shaken with lukewarm hydrous alcohol, and finally shaken and boiled with water. It is a thin, colorless liquid with little odor and taste, which decomposes wholly by distillation, yielding, before ebullition, carburetted hydrogen, a little carbonic acid and water, and then passing over colorless, but wholly decomposed, and giving no traces of sebacic acid, like common oleic acid. Bromeis in *An. der Ch. und Phar.* xlii.

BUTYRONE. *Chem.* First noticed by Chevreul as an aromatic volatile oil derived from the distillation of butyrate of lime. Submitted to the action of heat, it offers one of the most simple examples of decomposition of this kind. If a small quantity of pure and anhydrous butyrate of lime be heated with precaution, it soon decomposes into carbonic acid, which remains combined with the lime, and a volatile oil, which distils over, and is nearly pure or scarcely colored butyrene. The decomposi-

tion is thus represented, $\text{CaO}, \text{C}_8\text{H}_7\text{O}_3 = \text{CaO}, \text{CO}_2 + \text{C}_8\text{H}_7\text{O}$. By distilling somewhat considerable quantities of substance, there is a deposition of carbon, and a mixture of several liquid substances is obtained, in which butyrene is the chief product, constituting 42 to 43 per cent. of the salt. When this crude liquid is submitted to distillation, its boiling point is at first below 212° , but ascends rapidly to 284° ; the liquid, which passes between 284° and 293° , is butyrene, and is again distilled to render it pure. It forms a colorless limpid liquid, of a peculiar and penetrating odor, and with a burning taste; spec. grav. = 0.23; it boils at about 291° . It swims on water, in which it is almost insoluble, to which, however, it communicates its odor; it dissolves in every proportion in alcohol; it readily ignites, and burns with a luminous flame. It does not become colored by exposure to the air, although in the course of time it absorbs a considerable quantity of oxygen. Formula, $\text{C}_8\text{H}_7\text{O}$.

Butyronic acid. Gently heat a mixture of equal volumes of ordinary nitric acid and butyrene in a retort, and let the red vapors pass through water. The acid remains in the retort, and an ethereal liquid collects from the vapors; the former is poured into water and washed. It is an oily liquid, colored yellow, with an aromatic odor and a sweet taste; easily ignites, and burns with a reddish flame; is insoluble in water and soluble in alcohol in every proportion; heavier than water. It combines easily with bases, and affords crystallizable salts.

The following formulæ express the composition of the acid and of some of its salts:

Free acid..... $\text{C}_8\text{H}_6\text{O}, \text{NO}_4 + 2 \text{HO}$.
Salt of potash..... $\text{C}_8\text{H}_6\text{O}, \text{NO}_4 + \text{KO}, \text{HO}$.
Neutral salt of silver $\text{C}_8\text{H}_6\text{O}, \text{NO}_4 + 2 \text{AgO}$.
Acid " " $\text{C}_8\text{H}_6\text{O}, \text{NO}_4 + \text{AgO}, \text{HO}$.
Salt of lead..... $\text{C}_8\text{H}_6\text{O}, \text{NO}_4 + 2 \text{PbO}$.

By mixing an alcoholic solution of potassa with butyronic acid numerous crystals appear, which are purified by washing with alcohol; they are in the form of small laminæ of a beautiful yellow color; which at a temperature of about 212° ignite with a kind of explosion; a property common to the butyronates; it is nearly insoluble in alcohol; dissolves in about 20 times its weight of water; its aqueous solution precipitates salts of silver and of lead yellow, and salts of copper of a dirty green color. The salt of silver, at first yellow, becomes rapidly violet; is soluble in a large quantity of water, and crystallizes by spontaneous evaporation; if its aqueous solution be boiled, 1 equiv. of base is precipitated, and replaced by 1 equiv. of water.

BUXIN. *Chem.* An alkaloid said by Fauré to exist in all parts of the *Buxus sempervirens*, the bark containing 1 per cent. It is bitter, insoluble in water, soluble in alcohol, slightly in ether, reacts alkaline with reddened litmus, gives neutral salts with acids.

BYSSOLITE. *Min.* See **HORNBLÉNDE**.

BYTOWNITE. *Min.* Amorphous, having a granular structure; color greenish blue, lustre vitreous, translucent. *H.* = 6. *G.* = 2.805.

Analysis by Thomson, silica 47.735, alumina 390

29.695, lime 8.800, peroxide of iron 3.750, soda 7.600, magnesia, a trace, water 2.00 = 99.580. From Bytown, U. Canada. Allied to scapolite.

Form. $3 \left\{ \begin{matrix} \text{CaO} \\ \text{NaO} \\ \text{MgO} \end{matrix} \right\}, 2 \text{SiO}_3 + 3 \left\{ \begin{matrix} \text{Al}_2\text{O}_3 \\ \text{Fe}_2\text{O}_3 \end{matrix} \right\}, \text{SiO}_3 \quad (1)$

C.

CABBAGE. Schrader found in the expressed juice of the common cabbage, *Brassica oleracea*,

Green amylaceous matter..... 0.63
Albumen..... 0.29
Resin..... 0.05
Gummy extract..... 2.89
Extractive soluble in alcoh. and water 2.84,

together with sulphate and nitrate of potassa, chloride of potassium, malate and phosphate of lime, phosphates of magnesia, iron, and manganese. The var. *Botrytis*, cauliflower, yielded, according to Trommsdorf, 90 per cent. juice, which contained $\frac{1}{3}$ per cent. albumen, an extractive soluble in water, alcohol, and ether, fat, chlorophyll, free malic acid, oxalates of potassa, ammonia, and lime, chloride of sodium, sulphate and phosphate of lime; the skeleton remaining, contained resin, pectin, and pectic acid, a mucilaginous substance, soluble in boiling water, and on 1.8 per cent. of the weight of the cauliflower of fibre. Purple cabbage contains a blue coloring matter analogous to other fugitive blue colors, such as that of violets, &c.

CACAO. *Tech.* The seeds or bean of the *Theobroma Cacao* are made into chocolate and cocoa, or yield by expression an oily substance called Cacao-butter. The seed consists of the kernel and husk, the latter constituting 11.3 per cent. of the seed. Lampadius found in the kernel:

Oil..... 53.10
Albumen..... 16.70
Starch..... 10.91
Gum..... 7.75
Red coloring matter..... 2.01
Fibre..... 0.90
Water..... 5.28
Ashes..... 2.00

98.57

The ashes consisted mainly of phosphate of lime. The husk contained about 44 per cent. of a mucilaginous extract, 12.5 of a brown insoluble residue, and 5.6 ashes, containing much carbonate of potassa, little phosphate of lime and silica. By treating the alcoholic extract with water and evaporating, a carmine-red color is obtained, which is insoluble in ether, brightened by acids, blued by alkali, is precipitated blue by acetate of lead, lilac by tin-salt. The bean also contains an analogous substance to caffeine called **THEOBROMIN**.

Butter of Cacao. Obtained by pulverizing the warmed kernel, mixing it with 10 times its weight of boiling water, and pressing between warm tinned iron plates. It is purified by refusion with water, or on a small scale by boiling alcohol. The crude oil is yellowish with the

CACHOLONG.

odor and taste of the bean; the purified is colorless, inodorous, and tasteless; spec. grav. = 0.91; has the consistency of tallow, fuses at 86°; is very little liable to become rancid, and is hence adapted to ointments, &c., which are kept for a long time. It consists mainly of stearin, probably a little margarin, and a small quantity of olein.

CACHOLONG. See **QUARTZ**.

CACODYL. See **KAKODYL**.

CACOXENE. See **KAKOXENE**.

CACTIN. *Chem.* The flowers of *Cactus speciosus*, by extraction with spirit of wine, yield a carmine-red color, soluble in water, insoluble in alcohol and ether. After being thus extracted, a mixture of alcohol and ether extract 5—10 per cent. of a scarlet color, also soluble in water.

CADET'S LIQUID. See **KAKODYL**.

CADμία. A name applied by the Greeks to zinc-ore, in honor of Cadmus, who first introduced the manufacture of brass into Greece.

The same term is also applied to the impure oxide of zinc, which is deposited as a crust on the sides of furnaces in which zinc ores and brass are metallurgically treated. The metal cadmium was first observed in this crust. A similar crust is sometimes observed in iron blast-furnaces.

CADMIUM (καδμια, *calamine*). *Chem.* Cadmium exists alone as sulphuret, termed **GREENOCKITE**, and, associated with zinc, was discovered in 1818 by Stromeyer and Herrmann in oxide of zinc, since found in several of the ores of that metal, especially in a radiated blende from Przibram, Bohemia, which contains 2—3 per cent. of cadmium; in the blende of Nussière, 1½ per cent., in some of the zinc ores of Derbyshire, and in some zinc of commerce. (*Clarke.*) During the reduction of calamine, the very volatile cadmium flies off in vapor before the zinc, and collects in the roof of the arch, in a crust which often contains from 12 to 20 per cent. of cadmium.

Prep. The ore of cadmium, zinc, or cadmia is dissolved in dilute sulphuric acid, and after adding free acid, a current of sulphohydric acid gas is transmitted through the liquid, which precipitates the cadmium as sulphuret, while the zinc continues in solution; the sulphuret is then decomposed by concentrated chlorohydric acid, the solution evaporated to dryness, dissolved in water, and an excess of carbonate of ammonia added; the white carbonate of cadmium, which subsides, is heated to redness, mixed with charcoal, or soot, and exposed to a red heat, by which metallic cadmium is sublimed.

Prop. Cadmium crystallizes in 8-hedra, closely resembles tin in color and lustre, but is harder and more tenacious; is very sectile, ductile, and malleable; gives a cry like tin, but less distinct; spec. grav. = 8.604 before being hammered, and 8.694 afterwards. It melts at about the same temperature as tin, and is a little more volatile than mercury, condensing into globules with a metallic lustre; its vapor is inodorous. It becomes somewhat dull in the air, containing carbonic acid; under water free from carbonic acid, it is covered with white hydrated oxide; in air containing carbonic acid

CADMIUM.

a whitish gray coating forms containing carbonate. When heated in the open air, it burns readily to oxide with brownish yellow vapors. Cadmium is readily oxidized and dissolved by nitric acid, which is its best solvent. Sulphuric and hydrochloric acids added to water act upon it easily, developing hydrogen from the water. It decomposes steam only above its boiling point.

Symb. = Cd. Eq. 56 (697.5, O = 100).

Oxide of Cadmium. Prepared by igniting its carbonate, or nitrate, has an orange or brownish color, is fixed in the fire, and insoluble in water, spec. grav. = 8.18; is a strong base, forming neutral salts with acids; is precipitated as a white hydrate by pure ammonia, but is redissolved by excess of that alkali; is precipitated permanently by pure potassa or soda as a hydrate, and by all the alkaline carbonates as carbonate of oxide of cadmium. The hydrate attracts carbonic acid from the air, and loses its water at a red heat. Eq. = 64. CdO.

Salts of C. They are generally colorless; if soluble, have an alkaline reaction, a nauseous, metallic taste, and are emetic; they lose their acid, if volatile, by igniting; zinc precipitates dendritic metallic cadmium. Sulphuretted hydrogen, sulphohydrates, and the fresh sulphurets of iron, nickel, and cobalt precipitate sulphuret of cadmium at first yellow, then orange, the two first even from acid solutions. Caustic alkalies precipitate the white hydrate, soluble in excess of ammonia, not of the other two; neutral and acid carbonated alkalies throw down the white carbonate, insoluble in an excess of the precipitant, but if much free acid were present, the excess of carbonate of ammonia redissolves it. Phosphate of soda throws down phosphate of cadmium. Oxalic acid and alkaline oxalates precipitate the oxalate, soluble in ammonia. Yellow prussiate of potassa throws down a white, red prussiate, a yellow precipitate, soluble in muriatic acid. The salts of cadmium, insoluble in water, are soluble in sulphuric, muriatic, and nitric acids, and in the cold solutions of sulphate, muriate, nitrate, and succinate of ammonia.

Analysis. The yellow sulphuret affords one means of recognising its presence. When mixed with soda and heated on charcoal in the reducing flame of the blowpipe, the coal is coated with brownish red oxide. Cadmium may be weighed as sulphuret, but it is more accurate to precipitate the chloride by carbonate of potassa or soda. It is separated by sulphuretted hydrogen from the alkalies, earths, and the oxides of iron, manganese, zinc, nickel, cobalt, uranium, chrome, &c., by sulphuretted hydrogen; from lead by evaporating both as sulphates, and dissolving sulphate of cadmium by water; from bismuth approximately by precipitating the oxides with an excess of ammonia, which redissolves cadmium; from copper by precipitating them with an excess of carbonate of ammonia, and letting the filtered liquid stand to precipitate the remaining carbonate of cadmium; from arsenic, antimony, tin, and gold by dissolving the sulphurets in sulphhydrate of ammonium, in which that of cadmium is insoluble; from silver and mercury by chlorohydric acid.

CADMIUM.

Sulphuret of C. Occurs native as GREENOCKITE. Formed by fusing together sulphur and oxide of cadmium, or by adding sulphuretted hydrogen or a sulphohydrate to a solution of the metal.

Cd	56	77.78	78.02
S.....	16	22.22	21.98
CdS	72	100	100

Stromeyer.

It has a yellow color, inclining to orange, in proportion to the strength of the solution from which it is made; whenever heated to redness, it becomes first brown and then carmine red; bears a very strong heat without change, and in a white heat melts and crystallizes in transparent micaceous plates of a lemon-yellow color; dissolves readily in the cold in concentrated muriatic acid, while sulphuretted hydrogen gas is disengaged, and no sulphur is deposited; soluble in nitric acid.

Use. It is employed as a yellow pigment in oil-painting, from its brilliancy and fastness against light and other altering agents. To obtain it intimately mingled with alumina, a little alum may be added to a solution of cadmium and the whole precipitated by sulphhydrate of ammonium.

Carbosulphuret of sulphuret of Cad. is precipitated by adding the salt of lime to a solution of cadmium, of a lemon-yellow color, slightly soluble in water, with a yellow color.

Nitroguret of C. (?) Platinum-wire from the — pole of a Grove's battery is dipped into one end of a long glass vessel containing water and pieces of sal-ammoniac, while the + pole is connected with a piece of cadmium at the other end. A spongy lead-gray mass collects at the — pole, which has a spec. grav. 4.8, and yields nitrogen without hydrogen by heat.

Phosphuret of Cad. is gray, with a weak metallic lustre, very brittle, and melts with difficulty. Heated in the air it burns brilliantly to phosphate of cadmium; is soluble in chlorohydric acid. See *Alloys* under COPPER, MERCURY, and PLATINUM.

HALOID SALTS.

Chloride of C. Small transparent rectangular crystals; when heated they lose their water of crystallization and are converted into a transparent foliated crystallized mass, with a sub-metallic pearly lustre; when exposed to the air it falls down as a white powder; when strongly heated it sublimes in transparent micaceous scales.

Cd.....	56	61.27	61.39
Cl.....	35.5	38.73	38.61
CdCl	91.5	100	100

Stromeyer.

Chloride of Cad. and Potassium, KCl, CdCl. Formed by mixing strong solutions of the two salts, yields crystals, containing 1 eq. water, which change into others; anhydrous; rather soluble in water, somewhat in alcohol and wood-spirit.

Chloride of C. and Sodium, NaCl, CdCl, forms imperfect crystals, containing 4 eq. water, solu-

CADMIUM.

ble in 1.5 pts. water at 60°, a little in alcohol and wood-spirit.

Chloride of C. and Ammonium, NH₄Cl, CdCl, forms silvery needles with 1 eq. water, but they gradually disappear and are replaced by large rhombohedra, anhydrous; a little soluble in alcohol and wood-spirit.

Chloride of C. and Ammonia. Dry chloride of cadmium rapidly absorbs about 3 eq. ammonia-gas, 2 eq. of which it loses in the air, becoming NH₃, CdCl; the same is obtained by treating the chloride of C. with liquid ammonia as a white powder, soluble by warming, but separating on cooling.

Iodide of C. Formed either by heating the two substances together, or by digesting them in water. It crystallizes in large 6-sided tables, white, transparent, with a metallic lustre, inclined to pearly, and not altered by exposure to the air; they melt easily when heated, and reassume their crystalline form; when strongly heated, iodine is driven off. They dissolve easily in water and alcohol, and may be again obtained in crystals by evaporation.

Cd	56	30.77	30.54
I	126	69.23	69.46
CdI	182	100	100

Stromeyer.

Iodide of C. and Potassium, KI, CdI, amorphous, very soluble in water, a little in alcohol and wood-spirit.

Iodide of C. and Ammonia. The dry iodide absorbs 3 eq. ammonia by aid of heat to a white powder. The iodide warmed with liquid ammonia deposits small crystals of NH₃, CdI. Both are decomposed by water.

Bromide of C. Formed in the dry way by ignition, or in the wet way like the iodide. Long, white, efflorescent needles, very soluble in water, losing half their water at 212°, the rest at 392°. The dry bromide is very fusible, crystallizing on cooling, sublimes at a higher heat in white, pearly scales, is decomposed by hot nitric acid, and is soluble without change in muriatic and acetic acids, alcohol, and ether. The crystals contain:

			Croft.	Ramm.
CdBr.....	134.4	78.87	79.05	80.5
4 HO.....	36	21.13	20.95	19.5
CdBr + 4 HO	170.4	100	100	100

The dry bromide, CdBr, contains 41.66 per cent. cadmium by calculation, 41.47 by Berthelot's analysis.

Bromide of C. and Potassium, KB, CdBr. Needles, containing water; solubility like the iodide.

Bromide of C. and Ammonia. The dry bromide absorbs 2 eq. ammoniacal gas to a white voluminous powder. A strong solution of bromide, supersaturated with ammonia, yields by slow evaporation 8-hedra, with the formula, NH₃, CdBr.

Fluoride of C. CdF. Deposits by evaporation as a white crust, difficultly soluble in pure water, more soluble in fluohydric acid.

Silicofluoride of C. crystallizes in long, colorless, prismatic crystals, efflorescent in warm air.

CADMIUM.

OXYSALTS.

Sulphur. 1. *Sulphate.* Formed by dissolving the metal in nitrosulphuric acid, forms large, transparent, rectangular prisms, efflorescent in the air, very soluble in water, lose their water by a gentle heat, and by a stronger heat become the following basic sulphate. Composition :

	Stromeyer.		
CdO.....	64	45.72	45.96
SO ₃	40	28.57	28.52
4 HO.....	36	25.71	25.52
CdO, SO ₃ + 4 HO	140	100	100

2. The *basic sulphate* = 2CdO, SO₃ + HO, containing 72.32 per cent. oxide of C., 22.6 per cent. sulphuric acid, and 5.08 per cent. water.

3. Dry sulphate of C. absorbs 3 eq. ammoniacal gas, forming a white powder, soluble in water with the separation of oxide of cadmium.

4. *Sulphate of C. and Potassa* yields crystals of the oblique rhombic system.

5. *Sulphite of C.* Cadmium dissolves in liquid sulphurous acid with the formation of sulphite and sulphuret of cadmium; the hydrogen evolved decomposes sulphurous acid, forming sulphuretted hydrogen, by which the sulphuret of C. is precipitated. Thus, 3Cd + 3HO + 3SO₂ = 3(CdO, SO₂) + 3H, and 3H + SO₂ = HS + 2HO, and 3(CdO, SO₂) + HS = 2(CdO, SO₂) + CdS + SO₂ + HO.

6. *Hyposulphate of C.* Carbonate of C. dissolved in hyposulphuric acid gives a crystalline mass, very soluble in water and deliquescent. A solution of this salt in warm ammonia yields a crystalline powder, with the formula, CdO, S₂O₃ + 2NH₃.

Nitrate of C. crystallizes in prisms and needles cohering into a radiated mass; very soluble in water, deliquesces when exposed to the air; soluble in alcohol. Formula of the crystallized, CdO, NO₅ + 4HO, containing 41.56 per cent. oxide of C., and 35.07 per cent. nitric acid.

Phosphorus. 1. *Phosphate of C.*, formed by double decomposition with common phosphate of soda, is a white powder, insoluble in water, fusing at a white heat to a transparent glass.

2. *Metaphosphate of C.*, formed by adding metaphosphoric acid, and then ammonia to nitrate of cadmium. Microcosmic salt before the blowpipe dissolves a large quantity of oxide of C., forming a clear glass, which, when saturated, enamels white on cooling.

3. *Phosphite of C.* A white precipitate formed by double decomposition with sulphate of C. and phosphate of ammonia.

4. *Hypophosphite of C.* Liquid hypophosphorous acid is saturated with carbonate of cadmium, filtered, and evaporated in vacuo. It forms small crystals, which, by sublimation, yield phosphorus, hydrogen, and sulphuretted hydrogen, leaving phosphate of cadmium and a little oxide of phosphorus.

Halogens. 1. *Perchlorate of C.* The oxide, dissolved in perchloric acid, leaves on evaporation a transparent, crystalline mass, deliquescent, soluble in alcohol.

2. *Iodate of C.* Concentrated solution of iodate of soda and acetate of cadmium give a voluminous white precipitate, soon becoming

CAFFEIN.

a crystalline powder, soluble in excess of the cadmic salt, slightly in water, more so in nitric acid and ammonia. By distillation it yields oxygen and iodine-vapor, leaving a brownish red mixture of oxide and iodide of cadmium, insoluble in water (oxyiodide?)

3. *Bromate of C.* Precipitate sulphate of cadmium by bromate of baryta, filter, and evaporate under a glass with oil of vitriol. Transparent, rhombic prisms, of 127° and 53°, the acute edges replaced by a plane and beveled, terminated by 4 planes; soluble in 0.8 pts. cold water; when heated they act like the iodide, but the bromide is dissolved out by water. Composition :

	Ramm.		
CdO.....	64	33.44	33.38
BrO ₅	118.4	61.86	61.92
HO.....	9	4.70	4.70
CdO, BrO ₅ + HO	191.4	100	100

4. *Bromate of C. and Ammonia.* When a concentrated solution of 3 is mixed with ammonia until the precipitate redissolves, and evaporated spontaneously under a glass with lime, it yields crystals = 2(CdO, BrO₅) + 3NH₃.

Carbonate of C. A dry, white, insoluble powder, containing 74.42 per cent. oxide of cadmium. Form. = CdO, CO₂.

Eorate of C. Formed by double decomposition with borax and sulphate of cadmium; is a white powder, difficultly soluble in water, containing 72.115 per cent. oxide of cadmium. Before the blowpipe, borax dissolves oxide of C. to a clear, nearly colorless glass, which, when nearly saturated, may be rendered milk-white by an intermitting flame, or when more saturated becomes enamel-white, constantly boiling in giving off vapors of cadmium on charcoal. See other salts under metallic and organic acids.

CAFFEIN. *Chem.* A peculiar principle in coffee, &c. Discovered by Runge in 1820; Jobst proved the identity of Thein and Caffein, and Martius that of Guaranin and Caffein.

Prep. 1. A decoction of coffee is treated with subacetate of lead, as long as a greenish yellow precipitate appears, which is oxide of lead with coloring matter, and tanno-caffeic acid. A current of sulphuretted hydrogen gas is passed through the liquid after neutralizing the acetic acid with freshly precipitated oxide of lead, to throw down the excess of lead, and the filtered liquid concentrated, when the caffein is deposited in crystals. They are purified by repeated crystallization from boiling water.

2. Caffein may be entirely extracted by shaking the ethereal extract of coffee with water, precipitating the aqueous solution with subacetate of lead, removing the excess of lead by sulphuretted hydrogen, and crystallizing the filtered solution. *Rochleder* in *Wöhler and Liebig's Annal.* l. 231.

Prop. White needles, slightly flexible and transparent, with a silky lustre, feebly bitter, inodorous; soluble in 93 pts. of cold water, much more soluble in boiling water; soluble in 158 pts. absolute alcohol, and 298 pts. ether. (*Mulder.*) It combines with muriatic and sulphuric acids, forming large and beautiful crys-

CAFFEIC ACID.

tals; oil of vitriol decomposes it; nitric acid dissolves it without decomposition, and when the acid is evaporated the caffen remains unaltered; dry chlorine does not act on it. It is decomposed by boiling with barytic water. At 248° it loses 7·81 per cent. crystal-water; when heated to 350° it melts into a transparent liquid, and at about 720° it sublimes in fine needles unaltered.

According to Robiquet and Boutron, the quantity of caffen in different varieties of coffee is as follows:

In 100 pts. coffee from	Caffen.
Martinique	6·4
Alexandria	4·4
Java	4·4
Mocha	4·0
Cayenne	3·8
St. Domingo	3·2

It is still doubtful whether caffen should be regarded as an alkaloid or as belonging to some other class of organic compounds. Formula of the crystallized caffen, according to Liebig, Pfaff, and others, $C_8H_5N_2O_2$, or $C_{16}H_{10}N_4O_4$; that dried at 248° loses 2 eq. water. See COFFEE.

CAFFEIC ACID. *Chem. Prep.* A decoction of coffee is first precipitated by neutral acetate of lead, filtered, and then by subacetate of lead; the latter is mixed with water, the lead precipitated by sulphuretted hydrogen; the filtered liquid evaporated to the consistence of a syrup, and then mixed with its own bulk of alcohol. The portion held in solution is *tanno-caffenic acid*, that thrown down is *caffenic acid*, which is purified by washing with alcohol.

Prop. A white powder, insoluble in alcohol, soluble in water, with a brownish color; it reddens litmus-paper; ammonia, potassa, or soda give it a brown color, lime and barytic water precipitate it yellow; with salts of iron no change; with albumen a flocky precipitate, without any shade of green. Its characteristic property is, when strongly heated, to emit an aromatic odor precisely similar to that of roasted coffee. According to Pfaff, its constituents are, carbon 29·1, hydrogen 6·9, oxygen, 64·0.

CAINCIC ACID. *Chem.* Discovered in the root-bark of *Chiococca racemosa* of the order *Rubiaceæ*.

Prep. Evaporate the alcoholic solution of the root-bark to dryness, dissolve the residue on boiling water; add milk of lime to the solution till it loses all taste of bitterness; decompose this salt by oxalic acid dissolved in alcohol; the caincic acid thus obtained is purified by repeated solutions and crystallizations. Or it may be obtained directly from the concentrated decoction of the bark, by dropping into it muriatic acid, when the acid is deposited slowly, during several days, in small crystals.

Prop. Small white needles, inodorous, at first tasteless, but soon disagreeably bitter, very soluble in alcohol, requires 600 pts. water or ether for solution. At 212° it loses only a little water of crystallization; but when strongly heated in a glass tube it becomes soft, is charred, and gives out white vapors, which are deposited in small light crystals on the sides of the glass.

CALAMINE.

These crystals have no bitter taste and contain no ammonia.

Sulphuric acid dissolves caincic acid and chars it immediately. Muriatic, nitric, and acetic acids dissolve it, but change it almost immediately into a jelly, which is destitute of bitterness. Nitric acid heated with it produces a yellow bitter matter without any oxalic acid. With potassa, ammonia, baryta, and lime, it forms neutral salts, soluble in water and alcohol, and not crystallizable; the strong acids precipitate caincic acid; basic caincate of lime is insoluble in water, soluble in boiling alcohol, from which it is deposited in whitish flocks, which are strongly alkaline. Form. $C_8H_7O_4$ (?)

CAJEPUT-OIL. *Phar.* (Kayu-puti, *white wood*.) Prepared in the Moluccas by distilling with water the dry leaves and twigs of the *Melaleuca minor* (*leucadendron*). It is very fluid, of a light green color, and transparent; spec. grav. = 0·9274; taste hot; odor lively aromatic, camphoraceous; it boils at 347°. Potassium is converted by it into potassa; it dissolves iodine without explosion; sulphuric acid colors it yellow; cold nitric acid does not alter it. Formula, $C_{11}H_8O$. *Blanchet.*

The commercial oil is frequently adulterated. Its green color may be due to chlorophyll, possibly brightened by a little oxide of copper, but Pereira and Brande have detected no copper in it. It is often a mixture of oil of terpentine or lavender with camphor, but this may be detected by its boiling point, by explosion with iodine, or by distillation, which leaves camphor.

CALAITE. *Min.* Uncleavable Azure-spar, *M.* Turquoise, Agaphite, Johnite, Reniform.

H. = 6. G. = 2·83—3·00. Color a peculiar bluish green. Lustre somewhat waxy, internally dull, feebly subtranslucent—opaque. Fracture, small conchoidal.

Analysis. 1. From Jordansmühle in Silesia by John; 2, by Zellner:

	1.	2.
Phosphoric acid	30·90	38·9
Alumina	44·50	54·5
Oxide of copper	3·75	1·5
Oxide of iron	1·80	2·8
Water	19·00	1·0
	99·95	98·7

Behavior. In a closed tube it yields water and decrepitates violently, becoming black; colors the flame green, but is infusible; it fuses readily, however, with borax and mic. salt, giving the reaction of iron and copper. It is insoluble in acids.

Local. It occurs in Persia near Nishapuri. It receives a fine polish, and is valued for ornamental purposes; and when finely colored, is highly esteemed as a gem.

CALAMINE. *Min.* Rhombohedral Zinc-Baryte, *M.* Carbonate of Zinc; *Ger.* Zinkspath; *Galmey*, in part. *Descrip.* Cryst. system, Hexagonal, in hemiedric forms, the obtuse rhomb = 107° 40'; with perfect cleavage parallel to its planes. It also occurs reniform, botryoidal, stalactitic, granular, impalpable.

H. = 5. G. = 4·334—4·442. Color white, often grayish, greenish, brownish, sometimes green and brown; subtransparent, translucent; lustre

CALAMITE.

vitreous, inclining to pearly; streak white; brittle, with a fracture uneven, imperfectly conchoidal, and a white streak.

Analysis by Smithson; 1, from Somersetshire, and 2, from Derbyshire:

	1.	2.
Oxide of zinc.....	35.2	34.8
Carbonic acid.....	64.8	65.2
	100	100

It is therefore a simple carbonate of zinc, ZnO, CO_2 .

Behavior. In a closed tube it gives no water; on charcoal the carbonic acid is driven off, and oxide of zinc is obtained as a white coating, rarely colored yellow from cadmium. It dissolves with effervescence in acids, and quietly in potassa.

Local. It usually occurs in calcareous rocks, associated with other zinc ores, and generally with siliceous calamine.

CALAMITE. See **HORNBLende**.

CALAMUS. *Phar.* The fresh rhizome of the *Acorus Calamus* analyzed by Trommsdorff gave volatile oil 0.1, soft resin 2.3, extractive of a sharp sweetish taste with a little chloride of potassium 3.3, gum with phosphate of potassa 5.5, starch-like inulin 1.6, fibre 21.5, water 65.7. The taste of the root is due to the oil, which is obtained by distilling with water and employed for aromatic vinegar, &c. The oil is pale yellow, becoming reddish with time, has the odor and taste of the root; spec. grav. = 0.899. It consists of at least two oils, the more volatile of which contained 1 per cent. oxygen, and if purified would have the formula, C_5H_4 . The last portions distilling over contained 8.29 per cent. oxygen; the residuary oil would not distil over with water, and contained a large quantity of resin. *Schedermann.*

CALCAREOUS SPAR. *Min. Syn.* Rhombohedral Lime-Haloide, *M.*; Carbonate of Lime; Agaric Mineral, Anthraconite, Aphrite, Argentine, Calcite, Chalk, Iceland Spar, Inolite, Marble, Marl, Oolite, Ostreocolla, Peastone, Pisolite, Slate Spar, Satin Spar, Travertine, Tufa. *Ger.* Kalkspath.

Descrip. Cryst. system, Hexagonal, in hemiedric forms. The simple forms are rhombs and scalenohedra, with a 6-sided prism and terminal plane, but the number of the two former is such as to give rise to an extraordinary diversity in external appearance, thus, on the same crystal we may have right and left, obtuse and acute scalenohedra, as in dog-tooth spar. The radical rhomb, into which every crystal is perfectly cleavable = $105^\circ 5'$, there are 2 more obtuse, and 2 or 3 more acute rhombs. The radical rhomb is sometimes compounded parallel to a terminal edge; an acute rhomb or scalenohedron is often compounded parallel to the same edge, or parallel to the terminal plane. It is also found fibrous, lamellar, granular, compact, earthy, stalactitic.

H. = 2.5—3.5. **G.** = 2.508—2.788.

Color usually white; sometimes with a variety of shades of gray, red, green, yellow; also brown and black; transparent, opaque; lustre vitreous, subvitreous, earthy; the transparent

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varieties exhibit very distinctly double refraction; fracture obtained with difficulty from its easy cleavage.

Behavior and Analysis. It is composed of lime 56.29, and carbonic acid 43.7, with the formula, CaO, CO_2 . The colored varieties contain, in addition, small portions of iron, silica, magnesia, alumina, bitumen, plumbago, &c. Before the blowpipe, it is infusible; it loses, however, its carbonic acid, gives out an intense light, and ultimately is reduced to pure lime, or *quicklime*. Acids produce a brisk effervescence.

Varieties. *Iceland spar*, or double refracting spar, is applied to a variety crystallized in the form of the radical rhomb. *Satin spar* is fibrous, with a delicate silky lustre. *Oolite* consists of minute spherical particles, aggregated by a calcareous cement. The *Peastone*, or *Pisolite*, differs from oolite in the larger size of its particles, which are composed of concentric laminæ. *Chalk* is a massive opaque variety, usually white, and possessing a purely earthy aspect, and absence of lustre. *Agaric Mineral*, or *Rock Milk*, is a loose friable variety, deposited from waters containing carbonate of lime in solution. It is formed about lakes, whose waters are impregnated with lime; also in fissures in limestone, and in limestone caverns. *Marble* includes all the crystalline and earthy varieties which admit of a high polish. The *Stinkstone*, *Swinstone*, or *Anthraconite*, which is found columnar, granular, and compact, of various shades, emits a fetid odor, when struck with the hammer. *Argentine* possesses a silvery white lustre, and contains a little silica. *Marl* is a mixture of clay and carbonate of lime. *Calcareous Tufa* occurs in beds formed by deposition from water, and has a very porous structure. The *Fontainebleau Limestone* is an aggregate of the first acute rhomb, containing, mechanically mingled, large portions of sand. *Dana.*

Local. Carbonate of lime is one of the most extensively diffused simple salts, there being scarcely any district of country of some extent where it is wholly wanting. One of the most remarkable localities for crystals is in St. Lawrence and Jefferson counties, New York; a single crystal from this region in the cabinet of B. Silliman, Jr., is nearly transparent, and weighs 165 lbs.

Uses. The crystalline marbles and compact limestones are extensively employed in the construction of buildings, roads, &c.; a very compact variety is used in Lithography. Many of the varieties are employed indiscriminately as an alkaline flux in the reduction of ores, or are burned to caustic lime for cement or agriculture. See **CHALK**, **MARBLE**, **MARL**, and under **CALCIUM**.

CALCEDONY. See **QUARTZ**.

CALCINATION. A term employed in chemical research and the arts, and derived from the obsolete term *calx* applied to metallic oxides. It consists in exposing substances to a pretty strong heat over an open fire, so that the oxygen of the air oxidizes those substances capable of oxidation. The term is also applied less correctly to the ignition of substances either to expel some ingredient or to produce great dryness or incipient fusion or partial de-

composition, without reference to the action of the air.

CALCIUM. Carbonate of lime, under the form of marble, chalk, &c., and caustic lime or oxide of calcium have been known from the earliest times. Black proved in 1756 that mild lime (chalk, &c.) was quick-lime combined with carbonic acid. H. Davy, Berzelius and Pontin obtained calcium in 1808 from lime. Calcium is about equally abundant in nature with sodium, occurring chiefly as carbonate, then as silicate, sulphate, phosphate, fluoride, &c.

Calcium. The metal is prepared like barium, and is silver-white and solid; oxidizes rapidly at common temperatures in the air, and dissolves in water, as lime-water, evolving hydrogen. Eq. Ca. = 20 (251·942, Berz. O = 100). The last would give 20·15 by dividing by 12·5, the eq. of hydrogen.

Lime. Syn. Oxide of calcium; Ger. Kalk, Kalkerde; Fr. Chaux, Terre calcaire.

Prep. On a large scale by burning limestone, marble, chalk, oyster-shells in a kiln. (See LIME.) Prepared pure by igniting Iceland spar, Carrara marble, or pure precipitated carbonate of lime in a crucible at a red heat, moistening with water, and again igniting.

Prop. White, earthy, brittle, and pulverizable; spec. grav. 3·08—3·17; phosphoresces powerfully, when heated to full redness, like strontia and baryta; one of the most infusible bodies known, fusing with difficulty, even by the heat of the oxy-hydrogen blowpipe, to a white enamel. It has an alkaline taste, and reaction on reddened litmus, and is the least caustic of the alkaline bodies.

Composition:

			Berzelius.
Ca.....	20	71·43	71·91
O.....	8	28·57	28·09
CaO	28	100	100

Hydrate of Lime. If water be poured on newly burnt lime, it swells and falls to pieces, and is reduced to a very fine white powder, called *slacked lime*, producing so much heat as to vaporize a part of the water, and when the quantity of lime is large the heat produced is sufficient to fire combustibles; when lime is slacked with a little water in a dark place, light is also emitted. (*Pelletier.*) Two pts. lime and one pt. ice mixed at 32° combine rapidly, and the temperature rises to 212°. It may be obtained crystallized by placing lime-water under the air-pump, with concentrated sulphuric acid; the lime is deposited in small transparent six-sided prisms. *Gay-Lussac.*

Hydrate of lime loses its water by ignition; exposed to the air it absorbs carbonic acid, forming a mixed hydrate and carbonate.

Composition:

			Berzelius.
CaO.....	28	75·67	75·7 to 75·5
HO.....	9	24·33	24·3 " 24·5
CaO, HO	37	100	100

It is soluble in about 1200 pts. water at 212°

and about 600 at 32°, forming *lime-water*. The solution is limpid, has a feeble acrid taste, and changes vegetable blues to green; exposed to the air, a crust forms on its surface composed of carbonate of lime, which, when broken, subsides, and another succeeds it until the whole of the lime is precipitated. Hence, lime-water prepared by filtering water from slacked lime, should always be preserved in closely corked or stoppered bottles. *Milk of lime* is slacked lime suspended in lime-water, and when the former is present in some quantity it is termed *cream of lime*.

Salts of Lime. They are neutral, sometimes acid, colorless with colorless acids, the soluble have a disagreeable, rough, saline taste; a few give a reddish tint to the blowpipe and alcohol flame, but less brilliant and more orange than that of strontia. The soluble are the muriate, acetate, nitrate, &c.; most of the others are insoluble or difficultly soluble.

Analysis. A concentrated solution of a salt of lime is precipitated as a hydrate by caustic potassa or soda, not by ammonia, but if the solution do not precipitate by the alkali it absorbs carbonic acid rapidly from the air and then precipitates. With oxalate, carbonate, borate, phosphate, arseniate, arsenite, tartrate, and citrate of soda, it produces white precipitates, even when dilute, soluble in chlorohydric acid. Bicarbonate and sulphate of soda produce precipitates only in concentrated solutions; but a moderately dilute solution treated with sulphuric acid deposits needles of sulphate of lime after some time, while a very dilute solution will not, which distinguishes it from baryta and strontia; the sulphate being insoluble in 40 per cent. spirit of wine distinguishes it from magnesia. Oxalate of ammonia produces a cloudiness when 1 pt. lime is dissolved in 400·000 pts. water.

It is separated from most metals by sulphuretted hydrogen or sulphhydrate of ammonia; from the alkalies by oxalate of ammonia; from magnesia as the sulphate (see ANALYSIS, p. 187); from baryta by treating the dry chlorides with absolute alcohol, which dissolves chloride of calcium, or by precipitating a very dilute solution with sulphuric acid and washing; from strontia by dissolving the dry nitrates in absolute alcohol. Its quantity is estimated by weighing it as sulphate (ANALYSIS, p. 187), or by igniting the oxalate (p. 188).

Uses. It is employed in AGRICULTURE; as the basis of MORTAR; as a flux in metallurgy (see IRON and other metals); as a reagent by the chemist; in dyeing, &c.

Peroxide of Lime is prepared similarly to peroxide of barium, which it resembles in its properties.

Sulphur. 1. *Sulphuret of Calcium.* 1. Formed by passing sulphuretted hydrogen over lime in an ignited porcelain tube. 2. By mixing anhydrous sulphate of lime in powder with $\frac{1}{3}$ of its weight of charcoal powder, and exposing the mixture to a white heat; 100 pts. gypsum yield 51·5 pts. sulphuret of calcium. 3. Ignite lime or its carbonate with $\frac{1}{2}$ as much sulphur in a closed crucible; this yields 3 eq. sulphuret of calcium mixed with 1 eq. sulphate of lime.

Prop. Color reddish white, dissolves imper-

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fectly in water; the solution is colorless, hepatic, alkaline, and by evaporation in vacuo it yields white crystals. When prepared, as under 3, it is a pyrophorus, known under the name of *Canton's phosphorus*.

2. *Sulphurate of C.* Formed by passing sulphuretted hydrogen through water containing lime or sulphuret of calcium. Known only in solution, for by evaporation in vacuo or in hydrogen it deposits 1, evolving sulphuretted hydrogen.

3. *Bisulphuret of C.* By boiling a mixture of slacked lime, sulphur, and water, and allowing the liquid to cool slowly before it is perfectly saturated with sulphur, reddish yellow 4 or 6-sided prisms separate, which are permanent when dried in vacuo. They require 400 pts. water at 60° to dissolve them, less boiling water; moist air oxidizes them. Their crystall-water = 33.89 per cent., or 3 eq.; whence their formula = $\text{CaS}_2 + 3\text{HO}$.

4. *Quintisulphuret of C.* Boil sulphuret of calcium or slacked lime with water and sulphur. By using slacked lime, bisulphuret of calcium and hyposulphite of lime are formed at the same time. It is amorphous, drying to a reddish yellow mass, which by destructive distillation yields sulphur, leaving the sulphuret, 1; soluble in water and alcohol. Form. CaS_5 .

5. *Oxysulphuret of C.* Boil the sulphuret, from the decomposition of gypsum with charcoal, with much water, filter boiling hot, distil the liquid until the greater part has passed over, and let sulphate of lime crystallize out; on distilling again, golden yellow needles crystallize out, which, according to Rose's analysis, contain 42.51 per cent. water. Form. $= \text{CaS}_5 + 5\text{CaO} + 20\text{HO}$.

6. *Carbosulphuret of C.* Formed by digesting sulphuret of C., from gypsum and charcoal, with water and bisulphuret of carbon in excess, in a flask filled with it at the temperature of 86° until the sulphuret of C. is dissolved. A deep-red solution, yielding a yellowish brown sub-crystalline, saline mass, by evaporation in a vacuum; when fully dried, it leaves by resolution in water a reddish yellow basic salt, which is always formed if the sulphuret of carbon was not in excess. The neutral salt is soluble in alcohol, and decomposes by boiling.

Phosphuret of C. Formed by passing the vapor of phosphorus over fragments of quicklime at a low red heat. It is reddish brown, and consists of phosphate of lime and sulphuret of calcium; with an excess of phosphorus it is black, but by a gentle heat the excess may be distilled off; at a strong heat both are decomposed, giving off all the phosphorus and leaving lime. Heated in the air it burns to phosphate of lime. When put into water, it evolves sulphuretted hydrogen, forming hypophosphite of lime. If the water be acidulated with muriatic acid it yields much self-inflammable sulphuretted hydrogen.

Carburet of C. Acetate of lime, or a mixture of quicklime and sugar, is strongly ignited in a close vessel, and then heated between charcoal points, which terminate the electrodes of a strong Grove's battery, in a gas free from oxygen. The lime is reduced to a gray car-

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buret, which has a metallic lustre by friction, is not acted on by chlorohydric nor dilute sulphuric acid, and slowly by aqua-regia, the solution showing the presence of lime. Equal parts of lime and cyanide of mercury heated and similarly treated gave a gray metallic mass, containing less carbon, which oxidized in the air and evolved an odorous gas in water. *Hare*.

HALOID SALTS.

Chlorine. 1. *Chloride of Calcium.* Syn. *Muriate of lime.* *Ger.* Salzsaurer Kalk. *Fr.* Chlorure de Chaux. It exists in sea-water, many salines, and often in well-water. It is a residue in distilling ammonia from sal-ammoniac, and may be made by dissolving carbonate of lime in chlorohydric acid. The solution evaporated to a syrupy consistence often yields regular 6-sided prisms, but generally irregular striated prisms. Composition:

	<i>Berzelius.</i>		
CaCl.....	55.5	50.64	50.397
6 HO.....	54	49.36	49.603
CaCl, 6 Aq	109.5	100	100

This formula, $\text{CaCl} + 6\text{HO}$, corresponds to the most concentrated chlorohydric acid, $\text{HCl} + 6\text{HO}$. It fuses far below 212°; kept fused at 392°, it becomes porous, or kept in vacuo at summer temperature it becomes opaque, in both cases losing 4 eq. water; heated to below ignition it loses all its water, forming a white, porous mass, which is fusible to a dense translucent mass of a crystalline structure. If ignited with access of air it is partially decomposed, and lime formed. Composition:

	<i>Ure.</i>		
Ca.....	20	36.1	36.7
Cl.....	35.5	63.9	63.3
CaCl	55.5	100	100

Chloride of C. has a rough saline taste, is very deliquescent; the dry salt dissolves in water with evolution of heat, the crystallized produces a considerable degree of cold; 1 pt. of the latter dissolves in $\frac{1}{2}$ pt. water at 32°, in $\frac{1}{4}$ pt. at 60°; 10 pts. boiling absolute alcohol dissolve 7 pts. anhydrous chloride, and on cooling rectangular crystals separate containing 59 per cent. alcohol. The following table by Richter shows the spec. grav. and corresponding content of chloride in aqueous solutions:

Spec. grav.	Per cent.	Spec. grav.	Per cent.
1.45	41.91	1.21	23.93
1.42	40.43	1.18	20.85
1.39	38.31	1.15	17.60
1.36	36.49	1.12	14.42
1.33	34.57	1.09	11.23
1.30	32.35	1.06	7.66
1.27	29.67	1.03	3.95
1.24	26.86		

2. *Chloride of C. and Ammonia.* The chloride absorbs ammonia, falling to a white very voluminous powder, which takes fire in chlorine, and loses its ammonia by heat or water. Form $\text{CaCl} + 4\text{NH}_3$.

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3. *Oxychloride of C.* By boiling chloride of C. and slacked lime, or the residue from the preparation of caustic ammonia, with a little water, and filtering hot, the cooling solution deposits the salt in long thin needles, from which both alcohol and water extract the chloride and leave the lime. Form. $\text{CaCl}_2, 3\text{CaO} + 16\text{HO}$.

4. *Chromate of Chloride of C.* is a deliquescent salt. Form. $\text{CaCl}_2 + 2\text{CrO}_3$.

Bromine. 1. *Bromide of C.* Formed by igniting lime in bromine vapor, or by dissolving carbonate of lime in bromohydric acid, or by decomposing a solution of bromide of iron by lime, boiling in the air until the precipitate is brick-red and filtering. It is obtained with difficulty as colorless, silky needles. The anhydrous salt is white, with a sharp, bitter taste, fusible under partial decomposition, very soluble in water with evolution of heat, very soluble in alcohol; treated with oil of vitriol, it yields bromohydric acid, then bromine and sulphurous acid. Form. CaBr_2 , Eq. 98.4, containing 79.67 per cent. bromine.

2. *Bromide of C. and Ammonia.* The fused bromide, 1, absorbs ammonia, becoming a white voluminous powder, soluble in water. Form. $\text{CaBr}_2, 3\text{NH}_3$.

3. *Oxybromide of C.* By boiling 1 with milk of lime and filtering, fine needles are obtained similar to the oxychloride.

Iodide of C. Carbonate of lime dissolved in liquid iodohydric acid and evaporated, yields long needles on cooling the solution; it may be evaporated to dryness apart from the air, yielding a white mass, similar in taste to the chloride, which is fusible below a red heat, and then decomposes with access of air into lime and iodine. A strong solution of this salt dissolves much iodine, forming a black liquid, which, by evaporation in a vacuum over carbonate of potassa, yields large, black crystals of a metallic lustre, a periodide. (?) Lime precipitates from this solution a black, pulverulent, basic compound.

Fluorine. 1. *Fluoride of C.* It occurs rather abundantly distributed in the mineral kingdom, and is well known as **FLUOR SPAR**. It farther occurs in the bones of some animals, in some mineral springs. It may be prepared artificially by digesting freshly precipitated carbonate of lime in an excess of fluohydric acid, which gives it in the state of a granular white powder, easily washed. By mixing a solution of chloride of calcium with fluoride of potassium or sodium, it falls as a translucent, gelatinous mass, which it is very difficult to wash; but the addition of ammonia condenses it.

Prop. It fuses in a porcelain fire without farther change, congealing to a crystalline mass with 8-hedral cleavage. Both the native and artificial salt phosphoresces by heat. It is insoluble in water, slightly soluble in hot diluted chlorohydric acid, and is decomposed by sulphuric acid aided by gentle heat, and to some extent by boiling nitric acid. The vapor of anhydrous sulphuric acid does not decompose it, that of oil of vitriol readily. Cold oil of vitriol mixed with fluor spar in fine powder, converts it into a transparent syrupy mass, and no fluohydric acid is expelled till the mixture is heated to about 104° ; but if the spar con-

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tains silica, it effervesces when mixed with sulphuric acid, and becomes opaque from the formation of gypsum. Composition:

			<i>H. Davy.</i>
Ca.....	20	52.68	53.313
F.....	18.7	47.32	46.687
CaF	38.7	100	100-000, or

			<i>Berzelius.</i>	<i>H. Davy.</i>
CaO.....	28	72.35	72.6855	72.7
HF.....	10.7	27.65	27.3145	27.3
CaO, HF	38.7	100	100	100

Use. Fluoride of C. fuses with several salts, forming bodies which have not been minutely studied in reference to their chemical nature, but are of importance in fluxing, and the term *fluor spar* is due to its practical employment for this purpose. 1 eq. fluor spar fuses with 1 or 2 eq. carbonate of potassa to transparent liquid, which, on cooling, is translucent, lamellar-crystalline. With 1 eq. sulphate of soda it flows freely at a white heat, forming a translucent, granular-crystalline mass. It fuses also at a white heat with borax and common salt, the latter giving off white vapor and forming a translucent, lamellar-crystalline mass. With 1 eq. sulphate of baryta it fuses imperfectly, with 2 eq. the fusion is perfect, giving a translucent, subcrystalline mass. It fuses also with sulphuret of barium, and readily with the chloride. 1 eq. fluor spar with $\frac{1}{3}$, 1, and 2 eq. sulphate of lime fuses perfectly, but that with 1 eq. gypsum fuses most readily, yielding a highly crystalline mass; with 4 eq. the fusion is very imperfect. It also fuses with sulphuret of calcium. 4 pts. fluor spar and 7 pts. gypsum fuse on charcoal before the blowpipe to a transparent glass, cooling to a white enamel, and losing its fusibility after long-continued ignition.

2. *Borofluoride of C.* By the spontaneous evaporation of carbonate of lime dissolved in an excess of borofluohydric acid, or by mixing chloride of calcium and strong fluoride of boron, a gelatinous acid mass is obtained = $\text{CaF} + \text{BF}_3$. Water extracts an acid and leaves a basic salt.

3. *Silicofluoride of C.* Obtained by digesting a mixture of finely pulverized fluor spar and silica in dilute fluohydric acid, or by adding carbonate of lime to liquid silicofluohydric acid as long as it continues to dissolve, and evaporating by a gentle heat to crystallize. The crystals are oblique 4-sided prisms, perfectly soluble in the silicofluoric acid; digested in water it is partially decomposed, fluoride of calcium and silica being precipitated, while fluosilicic acid remains dissolved in the water. Form. $3\text{CaF} + 2\text{SiF}_3$.

OXYLSALTS.

Sulphur. 1. *Sulphate of Lime, a. Bihydrate.* Syn. Gypsum, Plaster of Paris, &c. Occurs native, crystallized, and granular (see **Gypsum**), constituting large formations; and may be formed directly from lime, or its carbonate, and oil of vitriol. Oil of vitriol poured over a large quantity of quick-lime heats to ignition,

and a more dilute acid exhibits light in the dark. It crystallizes from its solution in delicate white needles, spec. grav. = 2.322; it has scarcely any taste; is soluble in 460 pts. of cold, and in 450 of boiling water. Its solubility is increased by muriate and succinate of ammonia, by sulphate and muriate of soda. When heated, it begins to lose its water above 212°, loses it wholly at 270°, and falls into a soft white powder; at 212° under the air-pump with sulphuric acid it loses $\frac{1}{3}$ of its water. The white powder, when its water has been driven off at 270°, absorbs water very rapidly, and solidifies it, with a slight increase of temperature. When thus rendered anhydrous it is called *Boiled Plaster*, and is much employed in taking casts. If boiled or heated above 320° (or 400°) it is *burned*, so that it will not solidify with water, except by lapse of time, like *c*. Unboiled or crude plaster will also harden rapidly by using instead of water a solution of potassa, its carbonate, sulphate, or bisulphate, and instantaneously by tartrate of potassa and soda (Rochelle salt). The solidification in the former case is due to the reformation of the bihydrate, in the latter to the formation of double salts. The hardness of a plaster-cast is probably in proportion to the hardness of the gypsum from which it was made. It fuses at a strong red heat to a white, opaque, crystalline mass. Ignited with charcoal it is reduced to sulphuret of calcium. Composition:

	Berthier.		
CaO.....	28	32.56	32.8
SO ₃	40	46.51	45.2
2 HO.....	18	20.93	22.0
CaO, SO ₃ +2 Aq	86	100	100

b. Subhydrate. Found in a steam-boiler as a gray mass, composed of microscopic, transparent prisms; spec. grav. = 2.757. Formula, 2(CaO, SO₃) + HO.

c. Anhydrous. Found native (see ANHYDRITE), and is formed by strongly heating *a*; a white powder; spec. grav. = 2.93. Composition:

CaO.....	28	41.18
SO ₃	40	58.82
CaO, SO ₃	68	100

2. *Sulphate of L.* fuses readily with an equiv. of sulphate of potassa or soda. A native crystallized compound with the latter is termed GLAUBERITE.

3. *Hyposulphate of L.* Formed from hyposulphate of manganese and lime; the crystals resemble the salt of strontian; taste bitter; unaltered in the air; soluble in 0.8 pts. boiling water, and in 2.46 pts. of water at 66°; leaves 50.25 per cent. sulphate of lime by ignition. Form. CaO, S₂O₅ + 4 HO.

4. *Sulphite of L.* Prepared by saturating carbonate or milk of lime by sulphurous acid, or by mixing sulphite of potassa and chloride of calcium; it is a white powder; but from a solution in sulphurous acid, it crystallizes in 6-sided prisms, terminated by 6-sided pyramids; taste

slightly sulphurous; soluble in 800 pts. of cold water; exposed to the air it effloresces; when heated apart from the air, it is converted into sulphate of lime and sulphuret of calcium. Form. CaO, SO₂. It dissolves in sulphurous acid, forming a *bisulphite*.

5. *Hyposulphite of L.* Prep. 1. Boil flowers of sulphur, slacked lime, and water, and pass a current of sulphurous acid through the liquid, until the solution is decolorized. 2. A solution of sulphuret of lime is exposed to the air until it loses its color.

Prop. By evaporating the liquid at a temperature not exceeding 140°, it yields on cooling large transparent, 6-sided prisms; soluble in its own weight of water at 37°. Unaltered by exposure to the air, except when heated above 104°, when it effloresces; in a vacuum with oil of vitriol, it effloresces at common temperature. The salt is decomposed by heat in close vessels, giving off sulphur and leaving a mixture of sulphuret, sulphate, and probably sulphite; its saturated solution heated above 140°, separates into sulphite of lime and sulphur. Form. CaO, S₂O₂ + 6 HO.

Nitrogen. 1. *a. Nitrate of L.* Occurs in many pump-waters, particularly in cities, on walls of privies, in nitre-beds, in some limestone formations, &c. Prepared by dissolving carbonate of lime in nitric acid, and evaporating to a syrup, when it is precipitated in crystals, usually irregular. They are 6-sided prisms, terminated by long pyramids, oftener long needles; taste acrid and bitter; very soluble in water, 1 pt. water at 60° dissolving 4 pts. nitrate of lime, and boiling water every proportion. very soluble in alcohol; very deliquescent; when heated, it readily fuses, loses its water, becomes dry, and then often shines in the dark, whence the name of *Baldwin's phosphorus*; when strongly heated it gives off hyponitric acid and oxygen, leaving pure lime; detonates slightly with combustibles. Composition:

	Anhydrous.		Wenzel.	Longchamp.
CaO.....	28	34.14	33.8	34.885
NO ₅	54	65.86	66.2	65.115
CaO, NO ₅	82	100	100	100

Crystallized.			
CaO.....	28		23.73
NO ₅	54		45.76
4 HO.....	36		30.51
CaO, NO ₅ + 4 Aq		118	100

b. A basic nitrate is formed by boiling a saturated solution of 1. *a.* with slacked lime, and washing with alcohol of 40° Beaumé, which leaves the basic salt.

2. *Nitrite of L.* Formed like the salt of baryta by igniting nitrate of lime; is deliquescent; contains 27.34 per cent. lime.

Phosphorus. 1. *Phosphate. a. Neutral.* Obtained by dropping a solution of common phosphate of soda into one of chloride of calcium; the phosphate precipitates as a white crystalline powder; but a small quantity of basic salt is also formed; after drying it is a white

powder, tasteless, insoluble in water; very soluble in liquid acids, even in the carbonic, hence its presence in some mineral waters. Composition:

	Crystallized.	Berzelius.
2 CaO.....	56	34.27
PO ₅	71.4	43.70
4 HO.....	36	22.03
	163.4	100

After ignition it contains 56 per cent. phosphoric acid.

b. $\frac{1}{3}$ basic. Syn. Bone-ash, Bone earth; *Ger.* Knochenerde. It exists in the ashes of bones, and other parts of animals, and in plants.

Prep. 1. By reversing the preceding *a*, and dropping chloride of calcium into the phosphate, leaving an excess of the latter. 2. By dissolving bone-ash in chlorohydric acid, boiling to remove carbonic acid, and precipitating by ammonia.

Prop. A voluminous, gelatinous precipitate, condensing in drying to a hard, white, granular mass. Composition:

8 CaO	224	51.12
3 PO ₅	214.2	48.88
8 CaO, 3 PO ₅	438.2	100

It is decomposed partially or wholly by dilute sulphuric acid according to the quantity of the latter. 438.2 pts. (1 eq.) of the salt with 245 pts. (5 eq.) oil of vitriol yield sulphate and biphosphate of lime; $8 \text{ CaO}, 3 \text{ PO}_5 + 5 \text{ SO}_3 = 5 (\text{CaO}, \text{SO}_3) + 3 (\text{CaO}, \text{PO}_5)$; with 392 pts. (8 eq.) oil of vitriol it gives sulphate of lime and phosphoric acid; $8 \text{ CaO}, 3 \text{ PO}_5 + 8 \text{ SO}_3 = 8 (\text{CaO}, \text{SO}_3) + 3 \text{ PO}_5$. A portion of sulphate of lime remains with the phosphoric acid according to the quantity of water present, but it may be removed by adding alcohol. It is also decomposed by chlorohydric and nitric acids, forming a biphosphate. It is farther somewhat soluble in ammoniacal salts, chloride of sodium, &c.

It is fusible at an intense white heat to a white enamel. It is decomposed at a white heat with silica and charcoal, evolving carbonic oxide and phosphorus, and leaving silicate of lime. (See preparation of PHOSPHORUS.)

c. $\frac{1}{2}$ basic. Formed by precipitating a salt of lime by basic phosphate of soda, or by treating *b* with caustic soda. It occurs as a mineral combined with chloride or fluoride of calcium (see APATITE).

d. Sesquiphosphate. Formed by mixing a solution of phosphate of lime in phosphoric acid with alcohol; a white precipitate which reddens litmus even after washing with alcohol; water removes an acid phosphate, and leaves the neutral salt. Form. $4 \text{ CaO}, 3 \text{ PO}_5$.

e. Biphosphate. Formed by digesting phosphate of lime in phosphoric, muriatic, or nitric acid; it has an acid taste; forms laminæ or scales, and evaporating to dryness, it does not crystallize; deliquescent; soluble in water; by ignition it fuses into a transparent, tasteless glass, insoluble in water; by distillation with

charcoal the excess of acid is reduced, yielding phosphorus. Form. CaO, PO_5 .

f. Metaphosphate. Formed by igniting the preceding to a cloudy glass, or precipitating chloride of calcium by metaphosphate of soda. In the latter case it is hydrous, semifluid, transparent.

2. Phosphate of L. and Soda. Microcosmic salt (phosphate of soda and ammonia) dissolves a considerable quantity of lime before the blow-pipe, yielding a clear glass, which becomes milky on cooling, when saturated.

3. Phosphite of L. If phosphite of ammonia be mixed with chloride of calcium, a white crystalline crust precipitates after some time, which is soluble in water, and by ignition gives off water and pure hydrogen, leaving brownish neutral phosphate. Form. $2 \text{ CaO}, \text{PO}_3 + 2 \text{ HO}$.

4. Hypophosphite of L. *Prep.* 1. Add phosphorus gradually to boiling milk of lime, until the strong odor of phosphuretted hydrogen has diminished, pass carbonic acid through it and warm it to remove the excess of lime, and evaporate in a vacuum, or gently in the air. 2. Decompose phosphuretted calcium by boiling water, digest it, and treat it with carbonic acid, as above. *Prop.* Colorless, rectangular prisms, of a pearly and vitreous lustre; permanent in the air; of a nauseous, bitter taste; soluble in 6 pts. cold, but little more in boiling water, slightly soluble in dilute alcohol, insoluble in strong. Form. $\text{CaO}, \text{PO} + 2 \text{ HO}$, containing 32.79 per cent. lime and 20 or 21 per cent. water. The crystals lose their water above 572° ; heated to ignition in a retort, they evolve water, then very inflammable phosphuretted hydrogen, and leave a reddish residue of nearly neutral phosphate of lime and oxide of phosphorus; $2 (\text{CaO}, \text{PO} + 2 \text{ HO}) = 2 \text{ CaO}, \text{PO}_3 + \text{PH}_3 + \text{HO}$.

Halogen. 1. Chlorate of L. Formed by boiling chloride of lime in solution, or by dissolving lime in chloric acid, and evaporating to crystallize. Deliquescent, very soluble in water and alcohol, fusible in its crystal-water, detonating slightly on ignited coals.

2. Perchlorate of L. Formed directly, and evaporated to a syrup, congeals to a very deliquescent mass.

3. Chloride of L. The compounds of lime with hypochloric and chlorous acids have not been sufficiently investigated to allow of a description of their preparation or properties, but the late investigations of Millon and others into the nature of the acids of chlorine will soon throw a clearer light on this subject. Pure hydrate of lime absorbs about an equivalent of chlorine to form bleaching powder and bleaching liquid, which is probably a mixture of chloride of calcium and hypochlorite of lime, $\text{CaCl}, \text{CaO}, \text{ClO} + 2 \text{ HO}$. For their manufacture, see BLEACHING POWDER.

Both the dry and liquid chloride have a peculiar odor, due to hypochlorous acid; when heated they evolve oxygen, rarely chlorine, and the liquid is resolved into 1 eq. chlorate of lime + 17 eq. chloride of calcium, losing at the same time their bleaching power; at common temperatures, in close vessels, oxygen is evolved and chloride of calcium remains; the dry powder is deliquescent in the air and de-

CALCIUM.

CALCIUM.

composes similarly. Hence the necessity of excluding bleaching salts from light and air. Acids, even the carbonic, decompose it into a salt of lime and free chlorine; but if the solution be very dilute, the bleaching power continues for a considerable time. Carbonate of potassa or soda forms with it carbonate of lime and chlorated alkali.

4. *Iodate of L.* A portion of it crystallizes from a mixture of iodate of potassa and chloride of calcium. 4-sided prisms, efflorescent in the air, losing part of their water, soluble in 253 pts. water at 59°, in 75° boiling, in still less nitric acid. Composition:

<i>Rammelsberg.</i>			
CaO.....	28	11.71	12.57
IO ₅	166	69.46	68.60
5HO.....	45	18.83	18.83
CaO, IO ₅ +5HO	239	100	100

Before 392° it loses all its water, and by a gentle ignition it evolves 14.78 per cent. oxygen and 54.1 iodine, by a stronger heat 17.18 oxygen and 62.48 iodine, leaving in the latter case 20.34 per cent. of a mixture of $\frac{1}{5}$ periodate and much free lime. Composition of the dry salt:

CaO.....	28	14.43
IO ₅	166	85.57
CaO, IO ₅	194	100

5. *Periodate of L.* A basic salt precipitates from a mixture periodate of soda and nitrate of lime. A $\frac{4}{5}$ basic salt is formed by igniting iodate as above.

6. *Bromate of L.* Formed directly from the acid and lime or carbonate of lime. The crystals are soluble in 1.1 pt. cold water and the saturated solution is syrupy; they begin to lose their water at about 211° and lose it wholly at 356°; by ignition they are decomposed into oxygen and bromide of calcium. Composition:

<i>Rammelsberg.</i>			
CaO.....	28	18.02	18.092
BrO ₃	118.4	76.19	75.939
HO.....	9	5.79	5.969
CaO, BrO ₃ +HO	155.4	100	100

The dry salt contains 80.88 per cent. bromic acid.

1. *Carbonate of L. a. Anhydrous.* This salt exists in great abundance in nature, and is one of the most important and most generally used, next to common salt. It is found crystallized in 2 forms. (See *ARRAGONITE* and *CALCAREOUS SPAR*.) Formed by dissolving well-burned oyster-shells in muriatic acid, precipitating phosphate of lime by ammonia, filtering and precipitating by carbonate of ammonia. It is a white, subcrystalline powder, tasteless; spec. grav. = 2.717—2.99; scarcely soluble in pure and hot, more in cold water, but it is soluble in water containing carbonic acid; soluble in solutions of ammoniacal, less in potassa-salts; strong caustic potassa extracts carbonic acid; exposed to a red heat, it decrepitates, and loses

its acid at a higher heat; in a current of steam or other gases a lower degree of heat is required. (See *LIME*.) Under a strong pressure it melts at a red heat, assuming an appearance resembling *granular limestone*, while a small portion of carbonic acid, often from 1 to 5 per cent., is dissipated. A similar effect results by putting chalk into a crucible, pressing it down, and exposing it covered to a strong and quick heat in a furnace. Composition:

				<i>Dumas.</i>	<i>Berzelius.</i>
CaO.....	28	56	56.06	56.4	
CO ₂	22	44	43.94	43.6	
CaO, CO ₂	50	100	100	100	

b. Hydrous. A solution of 1 pt. lime and 3 pts. sugar in 6 pts. water exposed for some months to a cold air, or immediately to a 12-paired galvanic battery, deposits the salt in crystals, in the latter case at the platinum point of the positive electrode. Irregular rhombic or 6-sided prisms; spec. grav. = 1.75—1.78; unaltered in the air below 68°, but between 80° and 86° losing all their water; boiling spirit of wine abstracts all their water, boiling absolute alcohol only 2 eq. Form. CaO, CO₂ + 5 HO.

2. *Hydrocarbonate of L.* Half-burned lime, moistened with water, or quick-lime exposed for a month or two to the air becomes a mixed hydrate and carbonate, with the form. 2 CaO, CO₂, HO, or CaO, CO₂ + CaO, HO, containing 64.37 per cent. lime.

3. *Bicarbonate of Lime.* Formed by passing a current of carbonic acid through lime-water; if more water be added, a clear solution is effected; when a solution of lime is precipitated by an alkaline bicarbonate, the more dilute the liquid is the more lime remains in solution. It is only known in solution; hence the carbonate of lime frequently found in mineral waters. Exposed to the air, or by boiling, 1 eq. carbonic acid escapes, and neutral carbonate, 1. α , is precipitated. Hence the stony crust or deposit found in vessels in which water is boiled in limestone districts.

4. *Carbonate of L. and Soda.* Formed by fusing equal equiv. of each at a full red heat. It occurs as a mineral, crystallized and aqueous. See *GAY-LUSSITE*.

5. *Carbonate of L. and Baryta* occurs as a mineral. See *BARYTO-CALCITE*.

Borate of L. It occurs native with 5 eq. water (see *BOROCALCITE*), and probably as *RHODIZITE*. Formed artificially by precipitating a strong solution of lime by borax in excess. A soft, white mass, slightly soluble in water, readily in water containing sal-ammoniac or chloride of calcium; fusible to a glass. Formula of the air-dried, CaO, 2 BO₃ + HO, of the ignited salt, CaO, 2 BO₃, the former containing 65.29, the latter 71.31 per cent. boracic acid. Before the blowpipe, borax dissolves lime to a clear glass, which clouds by an intermitting flame; with a large content of lime, it cools to a crystalline mass with protruding points.

Silicates of L. 1. Anhydrous. 2 eq. silicic acid with 1 eq. carbonate of lime fuse to a homogeneous, vesicular, pearl-gray mass; 4 eq. silica with 3 eq. marble fuse with difficulty; 1 eq.

silica with 1 eq. marble fuse to a calcedonic, subcrystalline mass; 2 eq. silica with 3 eq. marble fuse to a vitreous, translucent mass. The two last are the most fusible.

Among minerals there are two silicates, the one neutral (see under *Ædelforsite*), the other $\frac{1}{2}$ basic, see *Table-spar*.

2. *Hydrous*. Hydraulic cement probably acts in part from the fixation of water by silica and lime. (See *MORTAR*.) Among minerals are *Danburite*, *Dysclasite*.

3. *Compound Silicates*. Silicate of lime enters into the composition of a large number of native silicates, such as *Hornblende*, *Augite*, *Pectolite*, &c., with protoxide bases only, *Scolezite*, *Scapolite*, &c., and many hydrous zeolitic minerals, with protoxide and sesquioxide bases. It also forms with silicated alkali several kinds of GLASS.

4. It farther unites with boracic acid in *Botryolite* and *Datholite*, with phosphates in *Sordawalite*, &c., with a chloride in *Eudialite*.

CALCULI. See CONCRETIONS and URINARY CALCULI.

CALEDONITE. *Min. Syn.* Paratamous Lead-Baryte, *Haid.* Cupreous Sulphato-Carbonate of Lead, Halblasurblei. *Descrip.* Cryst. Right Rhombic; the vert. prism. = 95°. Combines several 8-hedra and terminal planes of main and 2d lateral axis. The crystals sometimes large, but usually minute and divergent tufts. H. = 2.5—3. G. = 6.4. Color deep verdigris or bluish green; inclining to mountain-green if the crystals are delicate: lustre resinous; translucent; streak greenish white; rather brittle, with an uneven fracture.

Behavior and Analysis by Brooke. Easily reduced on charcoal; soluble with effervescence in nitric acid to a greenish liquid, with a residue of sulphate of lead.

Sulphate of lead.....	55.8
Carbonate of lead.....	32.8
Carbonate of copper.....	11.4

100

Formula, $3(\text{PbO}, \text{SO}_3) + 2(\text{PbO}, \text{CO}_2) + (\text{CuO}, \text{CO}_2)$.

It occurs only at Leadhills, in Scotland. See LEADHILLITE and DYOXALITE.

CALICO PRINTING. *Tech.* The art of topical dyeing, or producing various colored patterns on cloths, practised in Egypt, the East Indies, &c., from the earliest times, but greatly extended and improved since the commencement of the present century. The chemical principles of most of the processes are the same as those of dying, but other processes are added to these, and all of them taken together involve far more chemical knowledge than any other art whatever. Hence the rapid advances latterly made in this art in Europe from the employment of chemists in the Print-works, and when a similar system shall have been adopted in the United States more extensively than it is at present, we shall certainly witness a similar progress.

In order to heighten and give the proper effect to colors, the ground of the cloth is whitened or bleached (see BLEACHING). The methods

of producing the various patterns are almost as numerous as the patterns, but each color of a pattern is produced by one of six different styles, by combining which complicated patterns are attained.

1. *Mordant, Madder, or Chintz Style*. Designed for soluble organic colors, in which madder is chiefly used. The thickened mordant is first imprinted on the white cloth in patterns, and after the cloth has been aged and dunged, the color is imparted by passing the cloth through the dye-beck. On those portions of the cloth on which the mordant is applied, the coloring matter attaches itself in a durable manner, but on the unmordanted portions the color is feebly attached, so that it may be subsequently removed.

2. *Topical style*. Designed for steam and spirit colors. Coloring matters incompletely, or not at all, precipitated from their solutions when mixed with certain solutions of a mordant, are sometimes printed on the cloth with the mordant, and the fixation of the color is afterwards effected by exposing the cloth to steam. Some coloring matters applied topically in a state of solution become firmly attached to the cloth without a mordant and without the process of steaming, but merely by drying with exposure to the air. A solution of tin added to the mixtures impart greater brilliancy, but such spirit colors, unless steamed, are fugitive, whereas by steaming they are more permanent than without tin.

3. *Padding Style*. Chiefly employed for mineral colors. To produce a figure in a mineral color, the cloth is first printed with one of the two saline solutions, and afterwards uniformly impregnated with the other. To obtain a ground of a mineral color, one or both of the solutions may be applied by the padding machine.

4. *Resist style*. In the processes referable to the resist style, the white cloth is first imprinted with a substance called the *resist*, or *resist paste*, or *reserve paste*, which has the property of preventing those portions of the cloth on which it is applied from acquiring color when afterwards exposed to a dyeing liquid. They are of two kinds: one employed to prevent the attachment of a mordant, and the other that of a coloring matter.

5. *Discharge style*. Designed to produce a white or colored figure on a colored ground. It is effected by applying topically to the cloth already dyed or mordanted, a substance called the *discharge*, which has the property of decomposing or dissolving out either the coloring matter or the mordant. Chlorine and chromic acid are the common discharging agents for decomposing a vegetable or animal coloring matter, and an acid solution for dissolving a mordant. It is usually a topical bleaching. Mordants or color-bases may also be mixed with the discharge.

6. *China blue*. This peculiar style is practised only with indigo, which is printed on the cloth in its insoluble state, and is dissolved and transferred to the interior of the fibre by the successive application of lime and copperas, with exposure to the air.

The topical application of the color, mor-

dant, discharge, or resist, is made by five methods.

1. By a wooden block, with the design cut in relief, or formed by the insertion of narrow slips of flattened copper-wire. The block, worked by the hand, is charged with color, &c., by pressing it on the sieve, which is covered with the thickened coloring matter, &c., and then impressed on the cloth.

a represents the engraved cylinder or roller, made to revolve against two other cylinders, *b* and *c*. The cylinder *c*, covered with a woollen cloth, dips into the trough *d*, containing the solution of the thickened coloring matter, &c., and imparts some of it by rotation to the engraved roller *a*; *b* is a large iron drum or cylinder, with its surface rendered elastic by woollen cloth, and around it travels an endless web of blanket-stuff, *e*, in the direction of the arrows, accompanied by the calico, *f*, passing between it and the engraved cylinder.

The excess of coloring matter, &c., communicated to the engraved roller by the cylinder *c* is removed before it comes into contact with the calico; by scraping the surface of the roller as it revolves, by a sharp-edged plate, made of steel, or gun-metal, called the *color doctor* (*g*). A similar plate, on the opposite side, called the *lint doctor*, removes the fibres which the roller acquires from the calico.

The mordants, &c., for two, three, or even eight colors may be applied at the same time by having several engraved rollers with their appendages revolving simultaneously against the iron drum, as represented by the dotted cylinders and troughs, *h, h, i, i*.

4. By press printing, in which block printing with several colors may be executed at once. The printing surfaces are stereotype casts, and receive their colors from a cloth, covered with several colors in lines, which are brushed on the cloths by a brush that has been dipped into the colors contained in a box with as many divisions as there are colors, each division containing its color.

5. By surface printing, which is a modification of roller printing, the cylinder being made of wood instead of copper, with the pattern as in the ordinary block.

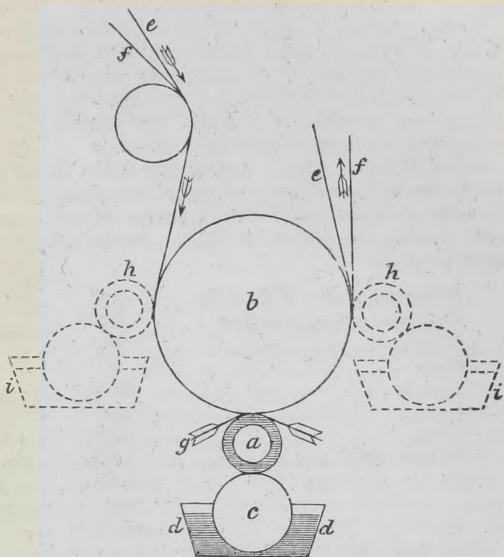
In order to print thin solutions, and at the same time to prevent their spreading beyond the lines of the design, the mordants, &c., are thickened with the following materials: 1. *Starch*, wheat, potatoe, rice, salep, sago, and flour; 2. *Altered Starch*, British gum, dextrin; 3. *Gum*, arabic, senegal, tragacanth; 4. *Inert substances*, Pipe-clay or kaolin, sulphate of lead, mixed with arabic or senegal gum. The most usual thickeners are wheat starch, flour, British gum, and gum arabic; tragacanth and salep are used with salts of tin and free acids. A colorless mordant is *sightened* or colored slightly with Brazil-wood, &c., to render it perceptible.

The objects of the present work will not allow a more minute description of the process pursued in color-printing; for to develop the chemical principles involved in them would be equivalent to a development of nearly all the

2. By a machine called the *Perrotine*, which executes block-printing by mechanical power, and is intermediate in its mode of working between block-printing and cylinder-printing.

3. By the cylinder-printing machine in which the pattern is engraved or impressed on copper cylinders. Fig. 35 will render the mode of employing this machine intelligible.

Fig. 35.



theory and practice of chemistry. For a somewhat more extended view the reader is referred to Parnell's "Applied Chemistry," vol. i., from which the above is mainly drawn. See also DYENG.

CALOMEL. *Med.* See Chloride of MERCURY.

CALOMEL. *Min.* See Horn MERCURY.

CALORIC. *Phys.* A term sometimes used to denote the cause of the sensation of HEAT.

CALORIMETER. *Phys.* An instrument employed by Lavoisier and Laplace to measure the quantities of latent heat given off by bodies on cooling, determined by the quantity of ice melted. Its determinations are inaccurate.

CALORIMOTOR. *Phys.* A galvanic apparatus contrived by Dr. Hare, which originally consisted of two large sheets of copper and zinc, wrapped spirally around each other with intervening pasteboard. At present it consists of a few pair of large flat plates of copper and zinc. The name is derived from its heating power. See DEFLAGRATOR.

CALOTROPIS. *Phar.* *Calotropis Gigantea* or *Mudarii*. The root-bark yielded in Duncan's analysis; mudarin 11.5; a white, waxy resin, slightly soluble in cold alcohol, and fusible at 194° 4.0; starch 8.0; besides gum, albumen, fixed oil, fibre, and water.

Mudarin is obtained by treating the alcoholic extract with water, in which it is soluble. It is transparent, light brown, extract-like, of a nauseous, bitter taste, very soluble in cold water and alcohol, not in ether, oil of olives, or terpentine. Its concentrated aqueous solution gradually heated to 74° is clouded, at 90° is

CALSTRONBARYTE.

opaque, at 95° gelatinizes, at 100° coagulates, at 180° it collects into a pitchy mass. It resembles albumen in this respect, being now insoluble until after some days, but alcohol restores its solubility at once. The coagulation does not take place when alcohol is present. Mudarin is nearly as strong an emetic as emetin.

CALSTRONBARYTE. *Min. Descrip.* Cryst. Right Rhombic, with a prismatic angle of 102½° to 103°; it occurs also in lamellar masses. H. = 3½. G. = 4.2–4.22. White, with vitreous and lustre; translucent; brittle.

Upon analysis, it gave 65.55 sulphate of baryta, 22.30 carbonate of strontia, 12.15 carbonate of lime; which is nearly the ratio of 4 (CaO, CO₂) + 5 (SrO, CO₂) + 9 (BaO, SO₃). It may be a mechanical mixture. Its locality is Schoharie county, New York. *Shepard.*

CALUMBIN. *Phar.* A principle found in the Calumbo root. The dried root of this plant, *Cocculus palmatus*, yielded to Planche 33 per cent. starch, 33 per cent. fibre. Buchner's analysis gives

Bitter substance with resin	12.2
Resinous coloring matter	5.0
Wax	0.2
Gum	4.7
Starch	25.0
Pectin	17.4
Fibre	12.6
Water, salts, and loss	12.9

100

Calumbin. Discovered by Wittstock and thus obtained. The root is treated 2 or 3 times with alcohol, of 0.835. The solutions mixed with ¾ of the alcohol, distilled off, and the residue allowed to remain for some days, until crystals are deposited. These are washed in cold water, dissolved in alcohol, the solution digested with bone black, and filtered, when, by concentration, it deposits pure calumbin; the mother-liquor still contains it.

Prop. Rhombic prisms, destitute of odor, with a very bitter taste; it fuses when heated, assuming the appearance of wax; it is neither acid nor alkaline; it is very little soluble in water, alcohol, or ether; boiling alcohol of 0.835 dissolves from 1/40 to 1/30 of its weight; sparingly soluble in volatile oils; sulphuric acid dissolves it, assuming first a yellow and then a red color; nitric acid of 1.25 dissolves it by heat, without decomposition. Boiling acetic acid of 1.04 is the best solvent; muriatic acid has very little action on it; it dissolves unaltered in caustic alkalies.

Liebig's analysis leads to no formula, the nearest being C₂₂H₁₂O₇(?) It acts poisonously on animals.

CALX. A term formerly applied to metallic oxides, originally designating limestone and lime. See **CALCINATION.**

CAMPEACHY WOOD. See **HEMATIN.**

CAMPHEN. *Chem.* A name applied to essential oils composed according to the formula, C₅H₄, or a multiple of it, and which combine directly with chlorohydric acid to a solid camphor-like or a volatile compound. It is more peculiarly applied to oil of terpentine. Dumas

CAMPHEN.

applied the term to the oil obtained from the muriate of terpentine-oil, which Blanchet and Sell termed Dady!; and Laurent assumed a radical, C₂₀H₁₆, in caryophyllin, &c., which he called camphen.

The Camphens have latterly received close investigations, especially the oil of terpentine. They are oils of terpentine, lemon, orange, capaiva-balsam, juniper, cubebs, and pepper. Others may belong to the series, such as oils of cloves, valerian, bergamot, &c., and caoutchouin is analogous to them. The camphens are characterized by passing into one or more isomeric modifications, according to a single or double chemical action, and hence they are divided into 3 orders. The camphens of the 1st order being the essential oils themselves, are peculiarly termed *Camphens*; those of the 2d order derived from the former by a single chemical reaction, are termed *Campherens*; those of the 3d order derived from the campherens by a single reaction, or from the 1st order by a double reaction, are termed *Camphilens*. Moreover, the same camphen may yield several campherens, and these again several camphilens, as shown in the following view:

CAMPHENS.

1st order, <i>Camphens.</i>	2d order, <i>Campherens.</i>	3d order, <i>Camphilens</i>
Oils of	Tereben	Terebilen
Terpentine	Colophen	Colophilen
Lemon	Citren	Citrilen
Copaiva-balsam	Copaiven	Copaivilen(?)

1st order. *Camphens.*

All the camphens are thus composed:

	In 100 pts.	Eq.	Vol.
Carbon	88.24	5	5
Hydrogen	11.76	4	8

Hence the simplest formula would be C₅H₄, but 1 eq. chlorohydric acid combining with 2, 3, or 4 times, C₅H₄, such products are adopted as the true formula, as shown by the following arrangement of essential oils:

4 (C ₅ H ₄) = C ₂₀ H ₁₆ .	3 (C ₅ H ₄) = C ₁₅ H ₁₂ .	2 (C ₅ H ₄) = C ₁₀ H ₈ .
Terpentine	Cubebs Pepper(?) Juniper	Lemon Orange Copaiva

Their preparation and peculiar properties, see under **ESSENTIAL OILS**, and under each oil. When pure they are colorless, almost odorless, with a burning aromatic taste, but assume a yellowish color and aromatic odor by access of air. They are peculiarly distinguished from camphens of the 2d and 3d orders by possessing the power of circular-polarization.

Compounds. 1. Oxides. The camphens all absorb oxygen and change into resinous bodies, which appear to be oxides, such as colophony (rosin) from terpentine, capaiva-balsam resin, &c.

2. Hydrate. Old oil of terpentine yields a crystallized hydrate, which has the composition, C₂₀H₁₆ + 4 HO. Another was obtained by Dumas and Peligot from the oils of terpentine, sweet basil (*Ocimum basilicum*), and small

cardamom, with the formula, $C_{20}H_{22}O_6$, or $C_{20}H_{16} + 6HO$. Similar compounds seem to form from oils of lemon and juniper.

3. Chlorohydrate of Camphen. Syn. Solid and liquid artificial camphor. Oil of juniper combines directly with chlorohydric acid gas without change. A part of oils of terpentine and cubebs combine with the acid unaltered, while another part is changed into a campheren. The other oils are wholly changed into campherens by muriatic acid. Chlorohydrate of terpentine oil has the form. $C_{20}H_{16} + HCl$, that of juniper and cubebs, $C_{15}H_{12} + HCl$, while that of pepper approaches the latter. They are prepared by passing chlorohydric gas through the pure oils of terpentine or cubebs until the liquid separates into a liquid and solid, the latter of which is pressed from the former, dissolved in boiling alcohol, from which it crystallizes, washed with alcohol, dried, mixed with quick-lime, and sublimed. The liquid is muriate of camphen.

These muriates have the same power of rotation as the oils from which they derive. That of camphen (terpentine) is white, amorphous, almost inodorous, neutral, volatile, like camphor, fuses at 239° , boils at 329 , losing its acid, burns with a green-bordered flame, insoluble in water, soluble in 3 pts. alcohol and in ether. Muriate of cubeb-oil forms long, rectangular prisms, is inodorous, tasteless, fuses at 268° , is very soluble in water. Muriate of juniper-oil is a viscid, colorless liquid. The muriates are decomposed, by passing their vapor over heated quick-lime, into a camphilen (3d order), without the power of rotation. Muriate of camphen is also decomposed by strong nitric acid, yielding a white crystalline body, by heated sulphuric acid, by chlorine with the formation of chloro-camphen.

4. Chlorocamphen. The yellow liquid obtained by treating the muriate with chlorine, suddenly changes by access of air into muriatic gas and crystalline chlorocamphen; $C_{20}H_{16} + HCl + Cl_3 = C_{20}H_{12}Cl_4 + 5HCl$. Formula, $C_{20}H_{12}Cl_4$. It resembles the muriate, 3; spec. grav. = 1.5; rotation = 0° ; fuses at 230° to 240° , and by a higher heat partly decomposes into muriatic acid and monochlorotereben.

5. Bromohydrate of Camphen, prepared like muriate, 3, resembles it in properties, its rotating power being unaltered; its alcoholic solution decomposes. Form. $C_{20}H_{16} + HBr$.

6. Iodohydrate of Camphen, is a colorless liquid; spec. grav. 1.509; decomposing rapidly in the air with separation of iodine.

Decomposition of Camphens. Those of oil of terpentine have been chiefly studied. Chlorine is largely absorbed by oil of terpentine, giving a thick, colorless liquid, of camphory odor, and sweetish bitter taste; spec. grav. 1.36; yields by distillation muriatic acid, muriate of camphen, chloro- and monochlorotereben, muriate of tereben, and residuary charcoal; the same products arising from a mixture of chlorocamphen and chlorotereben, it might be viewed as such, if it did not polarize to the right; distilled with strong nitric acid, it yields a colorless, crystalline product, and a residuary resinous substance. Formula, $C_{20}H_{12}Cl_4$, like chloro-camphen.

Bromine produces with terpentine oil a red fuming liquid; spec. grav. = 1.975; formula, $C_{20}H_{12}Br_4$, like bromotereben; apparently rotating right.

Iodine acts violently, almost explosively, as it does on some other essential oils; to an excess of terpentine oil it imparts a dark green color.

Oil of vitriol produces two campherens, viz. tereben and colophen. Strong nitric acid acts violently, even to combustion; a weaker acid produces among other products acetic acid; very dilute acid heated with the oil evolves nitrogen, carbonic acid, and oxide, leaving a basic resin, whose salts smell of formic acid. Gaseous hyponitric acid changes it into a black, brittle, resinous substance. Distilled over caustic alkali, oil of terpentine always leaves a blackish, flocculent residue.

2d Order. Campherens.

They are formed by the action of strong acids on the camphens, but some are known only in combination; tereben and colophen have been isolated. Their composition is

$C_{20}H_{16}$.	$C_{15}H_{12}$.	$C_{10}H_8$.
Tereben Colophen	Cubeben(?) (Not analyzed)	Citren Hesperiden Copaiven

Tereben and colophen are formed by mixing 20 pts. oil of terpentine with 1 pt. oil of vitriol, keeping the vessel cold, shaking, and letting it rest for 24 hours; the dark red liquid is poured off from the black deposit, distilled, and if it polarize, redistilled with oil of vitriol; carbonated alkali and chloride of calcium remove acid and water. By distilling at 410° to 428° , tereben passes over, above 430° colophen passes over, and if the latter be yellow from sulphur, it is removed by redistillation over an alloy of potassium and antimony. A more impure colophen is obtained by a rapid distillation of common rosin (colophony) over the naked fire.

The campherens have no power of rotation alone or in their combinations. Tereben is colorless, with an agreeable odor resembling thyme; spec. grav. and boiling point the same as oil of terpentine. Colophen and nearly all its compounds by transmitted light are colorless, by reflected light, against a dark ground, indigo-blue, or if yellow by transmitted they are green by reflected light; spec. grav. at $48^\circ = 0.940$, at $77^\circ = 0.9394$; boils between 590° and 599° .

Compounds. Solid and liquid chlorohydrates are formed in the same way as those of the camphens. 1. a. Subchlorohydrate of tereben, formed by passing chlorine into tereben, is a thin liquid; spec. grav. = 0.902 at 68° . Form. $2(C_{20}H_{16}) + HCl$. b. Chlorohydrate of tereben is the liquid formed by passing muriatic gas into oil of terpentine; its observed power of rotation is probably due to the presence of muriate of camphen. Formula, $C_{20}H_{16} + HCl$. 2. a. Subbromohydrate of tereben, $2(C_{20}H_{16}) + HBr$, is a liquid without rotation, formed by passing bromohydric acid through tereben. b. The bromohydrate, $C_{20}H_{16} + HBr$, is the liquid remaining in forming the bromohydrate

of camphen. 3. Subiodohydrate is formed like subbromohydrate. Iodohydrate is only obtained with iodohydrate of camphen. 4. *a.* Chlorotereben, $C_{20}H_{12}Cl_4$, is the product of the action of chlorine on tereben; a thick, colorless liquid; spec. grav. = 1.36 at 59°, without rotation; yields by distillation subchloro- and muriate of tereben. *b.* Subchlorotereben, $C_{20}H_{14}Cl_2$, a liquid of spec. grav. = 1.137 at 73½°. 5. Bromotereben, a thick red liquid of spec. grav. = 1.978 at 68°.

1. Muriate of Colophen. The crude liquid has a beautiful indigo-blue color. 2. Chlorocolophen. Colophen treated with chlorine is changed into a resin resembling common rosin, soluble in absolute alcohol, crystallizing in yellow needles. Formula, $C_{20}H_{16}Cl_2$, resembling oxide of camphen (rosin), in which the oxygen is replaced by chlorine. Chlorocolophen fused and treated farther with chlorine, yields a yellow compound containing more chlorine.

Chlorohydrates of Citren, Hesperiden, and Copaiven have all the formula, $C_{10}H_8 + HCl$. Chlorohydric acid forms with oil of lemons a liquid and solid compound of the same composition. The solid muriate of citren forms silvery laminæ, of a strong odor like the rubberose, fuses at 109°, sublimates at 122°, and boils at 320° with decomposition; decomposed by nitrate of silver or mercury in the cold. The muriate of hesperiden from oil of oranges is also solid and liquid; the former fuses at 122° and decomposes easily. Oil of copaiva is wholly changed by chlorohydric acid into a solid, forming transparent, rectangular prisms, slightly soluble in alcohol, very soluble in ether, decomposed by a salt of silver or mercury, fuses at 170°, decomposes at 284°–302°, boils at 365°.

The muriated campherens act towards sulphuric and nitric acids like those of camphen; heated with alkali they yield the camphilens.

3d Order. *Camphilens.*

They are all isomeric with their deriving camphens and campherens, and are obtained by passing the vapors of muriated camphen or campheren through a tube filled with caustic lime and heated by an oil-bath to 320° to 392°, until the product is free from muriatic acid; they are dried by chloride of calcium, redistilled over lime, and, if colored, over potassium. They have no power of rotation.

Camphilen. Syn. Regenerated oil of Terpentine, Camphen, Dadyl. Obtained from muriate of oil of terpentine, is colorless, aromatic, very like oil of terpentine, is very fluid; spec. grav. at 59° = 0.87; boils at 275°, which point rises towards the close of distillation to from 293° to 309°. It coincides in every respect with camphen (oil of terpentine) excepting in its rotary power.

Terebilen (Peucyl) is obtained from chlorohydrate of tereben; spec. grav. at 68° = 0.843; coincides in properties with camphilen.

Colophilen, obtained by distilling muriate of colophen over baryta, does not appear to possess the dichroism of colophen.

Citrilen (Citryl). Oils obtained from both solid and liquid muriate of citren, scarcely differ in appearance and odor from oil of

lemons, from the solid being almost identical, the other differing materially.

Copaivilen, Hesperidilen, Cubebilen, and Juniperilen have not been obtained.

Chlorohydric acid acts towards the camphilens as it does towards the camphens or oils, forming with camphilen and citrilen a solid and liquid, resembling muriate of the camphen except in its rotating power; with terebilen only a liquid. Iodohydric acid likewise forms a liquid with camphilen.

CAMPHINE. *Tech.* Purified oil of terpentine, employed for burning in lamps peculiarly constructed for it. Being a liquid rich in carbon, it is necessary to bring a large quantity of air in contact with it in a given time in order to prevent the flame from smoking and to produce great brilliancy. This is generally effected by not allowing the wick scarcely to rise above the containing cylinders, by the use of longer chimnies, by using an outer cylinder or cone which throws the outer current of air obliquely against the flame, and by the use of a movable button of the same diameter as the wick, and directly above it, by which the inner current of air is directed against the flame. The two counter currents of air supply sufficient oxygen in a given time to produce a white light of great intensity, and the amount of flame is regulated by raising or depressing the button, so that if it be depressed very low the flame is extinguished or burns blue.

CAMPHOR, including *Camphogen*, *Campholen*, *Campholone*, *Camphrone*, *Camphoric*, *Campholic*, and *Sulphocamphic acids*, *Bonëen* and *Borneole*.

CAMPHOR. A name sometimes loosely applied to the stearoptens of essential oils, but more definitely to the solid products obtained from the *Persea* (*Laurus*) *Camphora* growing in Japan, and the *Dryobalanops Camphora* in Borneo and Sumatra; the former being termed simply camphor, the latter Borneo-camphor. It is doubtful to which of these two some of the camphors obtained from essential oils belong, or whether there be a numerous series of camphors. The late experiments of Gerhardt prove that his Borneole derived from valerian is identical with Borneo-camphor.

Common Camphor (*Laurole*?) is obtained by boiling the chipped root and wood of *Persea C.* with water in a vessel to which a head or helm is attached filled with straw. The crude camphor is resublimed (refined) in the United States and in Europe. Common camphor or laurole is also formed, according to Gerhardt, by the reaction of nitric acid on Borneo-camphor or Borneole, as shown by the following equation, $C_{20}H_{18}O_2 + 2(NO_3, HO) = C_{20}H_{16}O_2 + 4HO + 2NO_4$. See *Borneole* below.

Refined camphor is a white, solid, apparently an aggregation of translucent, crystalline particles, of a strong and peculiar odor, an aromatic, burning, bitter taste; it is tough, but easily pulverizable, by moistening with alcohol. Spec. grav. = 0.9857–0.996; it melts at 347°, and boils at 400°, subliming entirely; exposed to the air, it evaporates completely. Pieces of camphor rotate on water; it is soluble in 1000 pts. water, and communicates to it its peculiar odor; it dissolves readily in less than 1 pt. alcohol of 0.806 at 54°, and is precipitated again

by water; it is also soluble in brandy, ether, fixed and volatile oils, in bisulphuret of carbon. It unites with iodine to a brown compound; it becomes fluid in chlorine without farther apparent change.

Claus described 6 compounds resulting from the decomposition of camphor with chloride of phosphorus, in which 1 to 6 eq. hydrogen are replaced by 1 to 6 eq. chlorine. By the action of iodine he obtained *Camphine*, $C_{18}H_{16}$, *Colophen*, *Camphocreasote*, and *Camphorosin* = $C_{22}H_{12}$.

By passing vapor of camphor over a heated mixture of lime and potassa, 2 eq. water are removed and a new hydrated acid, the *Camphoric*, is formed. By distilling camphor with anhydrous phosphoric acid, a fluid carbohydrate (*Camphogen*) is obtained. See both of these below.

Camphor is largely soluble in strong sulphuric acid, from which the greater part is separated by water unchanged; but if warmed sulphurous acid is evolved and a fluid oil distills over, having the odor of camphor and peppermint. If a mixture of camphor with 10 times its weight of sulphuric acid be warmed in a water-bath for several hours, scarcely any sulphurous acid evolves, and an oil separates on adding water, which has the same composition as camphor.

It is also soluble in strong nitric acid without change, forming an oily mixture; by boiling the solution *camphoric acid* is formed, and by distilling the residue after the separation of this acid, an oily liquid passes over, and then *anhydrous camphoric acid*. Composition of camphor:

10 C.....	60	78.95
8 H.....	8	10.53
1 O.....	8	10.52
	76	100

Borneo-camphor. *Borneole*. Its native origin, see above. It is formed artificially from oil of valerian, and probably from cubebs. The native camphor is found in the fissures or crevices of the wood, and obtained by cutting down the tree, dividing it into blocks, which are split into small pieces, from the interstices of which the camphor is extracted. It occurs in small white crystals, transparent, brittle, with a camphoraceous and peppery odor and a hot taste; its crystalline form is a 6-sided prism, of the rhombic system; it is heavier than water, very slightly soluble in it; but very soluble in alcohol and ether; it is fusible at 388° , and volatilizes at 414° .

When *Bornëen* (fluid *Borneo-camphor*), derived from oil of valerian, remains for some time in contact with caustic potassa lye, and is then distilled, the whole of it may be converted into *Borneole* (solid *Borneo-camphor*), particularly if alcohol be employed in the operation. The *bornëen* merely assumes the elements of water, thus $C_{20}H_{16} + 2HO = C_{20}H_{18}O_2$. *Borneole* resembles the native *borneo-camphor* in every respect, and its formula, found by Gerhardt, is precisely the same as that of the native found by Pelouze, viz. $C_{20}H_{18}O_2$.

Bornëen (Oil of Camphor). The native oil is obtained by incisions in the tree and catching

the oil; it is sometimes limpid, transparent, and colorless; but usually yellow or brownish; its odor is analogous to that of oil of cajeput, combined with camphor and with an odor of turpentine. It has been employed in the preparation of scented soap. The analyses of Martius and others prove that the oil was not pure, but consists, as Gerhardt has shown, of borneole dissolved in *bornëen*.

It may be obtained pure from oil of valerian by fractioning the distillation, subjecting the first portions to the action of fusing potassa in a retort, and rectifying repeatedly, catching only the first portions of the distillate. Repeated fractioned rectification of the native oil may yield pure *bornëen*; and the carbohydrate obtained by Pelouze by slightly heating *Borneo-camphor* with dry phosphoric acid is either identical or isomeric with *bornëen*.

Pure *bornëen* is lighter than water, colorless, with a terebinthic odor, but more pleasant, wholly volatile, boiling at 320° . It absorbs muriatic gas to a crystallized compound (see *muriate of CAMPHEN*); with caustic potassa lye it is wholly or partially converted into *Borneole*; by treatment with fuming nitric acid and neutralization with carbonate of soda, common camphor (*laurole*) is obtained, exclusively due to the dehydrogenation of the contained borneole, and not to the oxidation of *bornëen*. Formula = $C_{20}H_{16}$, which is the same as oil of turpentine. See *CAMPHEN*. By comparing *laurole* and borneole it will be observed that the former bears to borneole the same relation that aldehyde does to alcohol.

HYDRATED CAMPHORIC ACID. By heating in a retort 1 pt. camphor with 10 pts. concentrated nitric acid, it fuses to a dark yellow oily liquid, and by continued digestion with a renewal of the acid, the camphor disappears; the liquid is neutralized by carbonate of soda, poured off or filtered clear, concentrated and mixed with an excess of nitric acid, when the camphoric acid separates, which is washed with water and repeatedly crystallized.

It forms small, colorless, feathery, or prismatic crystals, of an acid and bitter taste; is slightly soluble in cold, more in hot water, very soluble in alcohol, ether, essential, and fat oils; fuses at 338° ; by dry distillation is resolved into water, and apparently anhydrous camphoric acid. Form. $C_{10}H_8O_4 = C_{10}H_7O_3 + HO$, containing 8.89 per cent. water.

Camphorates. The salts of potassa and soda are very soluble and difficult to crystallize; those of baryta, strontia, and protoxide of manganese are very soluble and crystallizable; most other metallic salts are insoluble. Camphorate of ammonia formed by gently warming the acid in dry ammonia, readily soluble in water, tasteless, inodorous; form. $NH_4O, \bar{Ca}$. By saturating a boiling solution of the acid with bicarbonate of ammonia and gently evaporating, small white prisms are obtained with the form. $2NH_4O, 3\bar{Ca}, HO + 9HO$; the latter 9 HO is lost by heating to 212° .

Bicamphorate of Ethyl (Camphovinic acid) is formed by distilling off $\frac{1}{2}$ of a mixture of 2 pts. camphoric acid, 4 alcohol, and 1 sulphuric acid, pouring water to the residue in the retort, dis-

solving the oily liquid in potassa, precipitating by muriatic acid, washing with water, and drying in vacuo over oil of vitriol. A colorless oily liquid, of a peculiar odor, disagreeable bitter taste; spec. grav. = 1.095 at 69°; slightly soluble in water, miscible with alcohol and ether; boiled with water separates into hydrated camphoric acid and camphoric ether; boils alone at 385°; and by a higher heat there distils over alcohol and a white crystalline body, which deposits from a boiling alcoholic solution anhydrous camphoric acid. Its formula is $\text{AeO}, \bar{\text{Ca}} + \text{HO}, \bar{\text{Ca}}$, and in forming double salts, the HO is replaced as usual, with an eq. of the metallic oxide. Its alkaline salts are soluble in water. The silver-salt, $\text{AeO}, \bar{\text{Ca}} + \text{AgO}, \bar{\text{Ca}}$, is white, gelatinous, somewhat soluble.

Camphorate of Ethyl (Camphoric ether), obtained from the alcoholic solution of the distilled bicamphorate, is an oily liquid, of a very disagreeable, bitter taste, a nauseous odor; spec. grav. 1.029 at 61°; boils at 545°; burns with difficulty with a smoky flame, insoluble in water, very soluble in alcohol and ether; chlorine forms with it chlorocamphoric ether. Form. $\text{AeO}, \bar{\text{Ca}} = \text{C}_4\text{H}_5\text{O} + \text{C}_{10}\text{H}_7\text{O}_3 = \text{C}_{14}\text{H}_{12}\text{O}_4$.

ANHYDROUS CAMPHORIC ACID. According to Liebig, this substance is not anhydrous camphoric acid, although of the same composition, for its salts have different properties from the camphorates. It is formed as above from bicamphorate of ethyl. It forms colorless, shining prisms, with rhombic basis; spec. grav. = 1.194 at 69°; has but little taste, not acid, but somewhat resembling that of benzoic acid, slightly soluble in cold, a little more in hot water; by boiling the solution for several hours it is changed into the hydrated acid; more soluble in cold, very soluble in boiling alcohol; sublimes at 266°, fuses at 423°; distils in ammonia-gas to yellowish liquid, which evolves no ammonia by boiling with potassa.

Anhydrous Camphorates. They differ from the camphorates in form; its alcoholic solution does not precipitate acetate of lead; nor its ammoniacal salt solutions of copper, lead, or silver. The ammoniacal salt, obtained by dissolving the acid in carbonated or caustic ammonia, and gentle evaporation to a syrup, congeals after some days to a crystalline mass; fusible at 212°, very soluble in water, from which the mineral acids do not precipitate hydrated camphoric acid, but an acid terpentine-like mass. Form. $\text{NH}_4\text{O}, \text{C}_{10}\text{H}_7\text{O}_3$. The salt of potassa forms broad pearly scales, that of the hydrous acid fine needles.

CAMPHOSULPHURIC ACID. *Prep.* Dissolve anhydrous camphoric acid in fuming oil of vitriol to saturation, warm it in a water-bath as long as gas evolves, which is only carbonic oxide, then pour the liquid gradually into water, neutralize with carbonate of baryta and filter. The solution contains camphosulphate of baryta, from which, by sulphuric acid or from the lead salt by sulphuretted hydrogen, the pure acid may be prepared; or it may be obtained directly from the sulphuric acid solution, when dilute, by evaporation in vacuo, and repeated crystallization from alcohol.

Prop. Colorless 6-sided prisms, of acid taste,

very soluble in water, alcohol, and ether, insoluble in oil of terpentine and bisulphuret of carbon; fuse between 320° and 331°, before which they decompose. Form. of the crystals, $\text{C}_9\text{H}_7\text{O}_3, \text{SO}_2 + 3\text{HO}$; 2 eq. of the crystal-water pass off in vacuo.

The salt of *potassa* prepared from an alcoholic solution of the acid and potassa is neutral and crystallized; from an aqueous solution forms an acid and a basic salt. Form. of the neutral, $\text{KO}, \text{C}_9\text{H}_7\text{O}_3, \text{SO}_2$. The ammoniacal salt, formed directly, is crystallized; form. = $\text{NH}_4\text{O}, \text{C}_9\text{H}_7\text{O}_3, \text{SO}_2 + \text{HO}$. The salt of *baryta* is a colorless, gummy mass; that of *lead* amorphous; that of *silver* a crystalline crust; these three salts have a sweetish taste, the two former very soluble in water, and all the above salts are scarcely or not at all in alcohol.

CAMPHOGEN. Formed by distilling camphor (laurole) with dry phosphoric acid (*Dumas*), or from oil of cumin, in which it exists ready formed (*Gerhardt and Cahours*). See **CYMEN**. It is a colorless liquid, spec. grav. = 0.86 at 55°, boils at 347, forms sulphocamphoric acid with fuming sulphuric acid; formula = $\text{C}_{20}\text{H}_{14}$.

SULPHOCAMPHRIC ACID. Formed by warming camphogen with a slight excess of fuming sulphuric acid in a water-bath, saturating with carbonate of lead, and decomposing the latter by sulphuretted hydrogen. Form. = $\text{C}_{20}\text{H}_{13}, \text{S}_2\text{O}_5$. The salt of *lead* forms pearly laminæ, of the composition $\text{PbO}, \text{C}_{20}\text{H}_{13}, \text{S}_2\text{O}_5 + 4\text{HO}$; the water (= 10.1 per cent.) passes off at 248°. The salt of *baryta* resembles the preceding in form and composition. The salts of this acid are identical with those of sulphocymenic acid. See **CYMEN**.

CAMPHOLIC ACID. A fused mixture of lime and potassa is introduced into a tube, the vapor of camphor passed repeatedly over it at between 570° and 750°, and the mixture treated with boiling water; from the filtrate the acid deposits white and crystalline; after washing and drying it fuses at 176°, boils at 482°, distilling entirely; is insoluble in water, very soluble in alcohol and ether, from a mixture of which it crystallizes readily. Form. = $\text{C}_{20}\text{H}_{17}\text{O}_3 + \text{HO}$. Campholate of lime is white, crystalline, more soluble in cold than hot water. The silver-salt is a white caseous precipitate. *Delalande*.

CAMPHOLONE is a liquid obtained by distilling campholate of lime, and probably has the formula $\text{C}_{19}\text{H}_{17}\text{O}$.

CAMPHOLEN is a liquid carbohydrogen, boiling at 275°, obtained by distilling campholic acid with dry phosphoric acid, and has the formula $\text{C}_{18}\text{H}_{16}$.

CAMPHRONE, obtained by passing vapor of camphor over lime at a low red heat, is a colorless, thin, oily fluid, boiling at 167°, of the composition, $\text{C}_{30}\text{H}_{22}\text{O}$. *Fremy*.

CANADA-BALSAM. *Phar.* A balsam or terpentine obtained from the Balm of Gilead Fir (*Abies balsamea*). It is light, yellowish, transparent, of an agreeable terebinthic odor, a slightly bitter and acrid taste, flowing like thin honey when fresh, but solidifying by time. Bonastre's analysis gave, *essential oil* 18.6, *resin* easily soluble in alcohol 40.0, *resin* difficultly soluble 33.4, *elastic resin* 4.0, *bitter extractive* and *salts* 4.0.

CANCRINITE. *Min. Descrip.* Cryst. hexagonal, of a rose-red color.

H. = 5·5—6. G. = 2·453. Fusible to a white vesicular glass; effervesces with mic. salt, leaving a skeleton of silica; soluble with effervescence in chlorohydric acid, and gelatinizing even after ignition. The following is the average of two analyses by G. Rose:

Silica	40·42
Alumina	28·27
Soda	17·52
Potassa	0·69
Lime	6·70
Carbonic acid	6·38

99·98

Hence the formula, $2\text{NaO}, \text{SiO}_3 + 2(\text{Al}_2\text{O}_3, \text{SiO}_3) + \text{CaO}, \text{CO}_2$. It occurs near Miask, in the Ilmen mountains, Ural, associated with Sodalite, Nepheline, &c., to which it is allied. Refer to them.

CANDLES. *Tech.* Solid fatty matters formed into long cylinders, with a wick passing through the axis, and used for illumination. The loosely twisted wick, by capillary action, carries up the melted fat, which is then converted into inflammable gases, burning with a more or less white flame.

There are several kinds in use. The *dip* candle is made by successively dipping the suspended wick into melted tallow or mixed fats, a layer adhering at each dip. The *mould* candle is made by casting melted tallow into metallic cylinders with the wick in the centre. *Stearine* candles are moulded from the harder portions of tallow, lard, &c., obtained by pressing the fats warm. *Stearic acid* lights are moulded from stearic acid, *sperm* candles from spermaceti. Sperm candles yield the whitest light, but good stearic acid is scarcely inferior to them. Candles of sperm, stearic acid, and stearin requiring a higher temperature to soften them, they are well adapted to tropical climates. The dip candle is at present chiefly of domestic manufacture and employed in the country. See SPERMACETI, STEARIN, &c.

CANDITE. See SPINEL.

CANDY. *Tech.* Applied to sugars, which are not crystallized, or to well-formed crystals; the latter are termed sugar-candy. Molasses evaporated so far as to become solid on cooling, forms molasses-candy. Some light-colored candies made from pure cane-sugar are made by confectioners, in which the sugar is unquestionably altered, for as long as it tends strongly to crystallize, such candies do not form a cohering mass; and hence the crystalline character is artificially destroyed by means of acid salts, &c. Mixtures of pure sugar with flour, starch, &c., constitute other varieties of candy.

CANELLA ALBA. *Phar.* Petroz and Robinet found a substance in this bark, which they termed Canellin; it was crystallized, sweetish, not fermentable, very soluble in water and spirit of wine, not in absolute alcohol.

Meyer and Reiche found the oil of the bark to contain at least three different oils: 1st, a heavy oil, which combines with bases, and is perfectly identical in odor and composition with

peppermint oil; 2d, a light oil, which constitutes by far the larger portion, and which appears to be identical with cajeput oil; and, 3d, a heavy oil, which does not combine with bases, and is present only in small quantity. They have also confirmed the statement that this bark contains an unusually large amount of mannite (above 8 per cent.). *Chem. Gaz.* i. 526.

CANNA. A starch latterly employed in Europe, derived from an unknown species of canna, and termed also *Tous les Mois*.

CANNABIN. See HEMP.

CANNEL COAL. See COAL.

CANNON METAL. See BRONZE.

CANTHARIDIN. Syn. Vesicatorin; Cantharides-Camphor. Found in *Cantharides vesicatoria*, *Lytta vittata*, *Mylabris Cichorii*, and other vesicating insects.

Prep. By concentrating an alcoholic tincture and setting aside, the cantharidin slowly crystallizes and is purified by washing with cold alcohol, and boiling with alcohol and animal charcoal.

Prop. Crystallizes in micaceous plates, fusible to a yellow oil, which by a stronger heat is vaporizable, forming white vapors, condensable into acicular crystals of cantharidin. When isolated, not soluble in water, but becomes so with the other constituents of cantharides; hence an aqueous infusion of the insects contains cantharidin; easily soluble in ether, volatile and fixed oils, and hot spirit of wine; and from the latter it separates as the liquid cools. Concentrated boiling sulphuric, nitric, and muriatic acids dissolve it without change; it is dissolved by potassa and soda. Formula, $\text{C}_{10}\text{H}_6\text{O}_4$. (?) *Regnault*.

CANTON'S PHOSPHORUS. See Sulphuret of CALCIUM.

CAOUTCHOUC. Syn. India Rubber, Gum Elastic; *Ger.* Federharz, Elastisches Harz. A vegetable principle existing in the milky juices of many genera and species of plants; and hence there may be several varieties of it. It is obtained from the *Siphonia elastica*, *S. Cahuchu* of S. America; *Artocarpus incisa*, *integrifolia* of the West Indies; *Urceola elastica* of Sumatra and Java; *Ficus elastica*, *religiosa*, *indica*, &c. of the East Indies; farther from the *Castilleja elastica*, *Cecropia peltata*, *Hippomene biglandulosa*. It exists in the milk of many Euphorbiaceæ, Papaveraceæ, in *Lactuca*, *Asclepias*, *Leontodon*, &c., &c. According to Nees v. Esenbeck and C. Marquart it is only in the stem of the *Ficus elastica*, for the juice of the leaves and branches yield viscin (see BIRDLIME).

When any of these plants is incised, there exudes a milky juice, which, by exposure to the air, gradually lets fall concrete caoutchouc. The juice is pale yellow, thick, and similar to cream; its odor is sourish and putrid; spec. grav. = 1·01174; when spread in thin layers on a solid body it soon becomes solid caoutchouc, amounting to 45 per cent. of the weight of the juice.

Faraday's analysis of the juice gave, caoutchouc 31·7, albumen 1·9, a bitter nitrogenous matter, soluble in water and alcohol, and precipitable by nitrate of lead, 7·13, a substance insoluble in water and alcohol 2·9, water with a little free acid 56·37. The caoutchouc floats

in it in globules, and it is immediately congealed by heat or alcohol; the particles deposit by standing; it is miscible in all proportions with water.

Caoutchouc has a pale yellow color, and is destitute both of taste and smell. The black color of caoutchouc is owing to the method of drying it after it has been spread upon moulds; by exposing it to smoke, after each successive coat. At 32° it is hard, and has little elasticity, but when heated to 60° or 70°, becomes soft and pliable like leather, is exceedingly elastic and adhesive; and cannot be broken without considerable force. Spec. grav. = 0.9335.

The caoutchouc in thick masses or cakes, is porous and white internally, and has a characteristic caseous odor.

To prepare pure caoutchouc, the juice is mixed with 4 times as much water, suffered to stand for 24 hours, the liquid beneath the gum drawn off, and this operation repeated as long as any thing dissolves. The globules are separated from the water by adding salt or muriatic acid to it, and subsequently washing with pure water; it is dried by evaporation or by bibulous paper. When dry it is white and opaque, but after completely drying is transparent and colorless in thin layers. Spec. grav. = 0.925.

Caoutchouc is insoluble in water, alcohol, acids, or alkalies; by long boiling in water it softens and swells up, and is then acted on with greater facility by different menstrua, but when exposed to the air, it resumes its former state.

Caoutchouc is slightly soluble in ether (1 drachm in 8 ounces) by washing the ether previously in water; alcohol precipitates the caoutchouc from this solution; the residue is merely swollen with ether. When the ether is evaporated, the caoutchouc is obtained unaltered. It is soluble in volatile oils and cold naphtha, a portion dissolving, the rest merely swelling, but when the oils are evaporated, it often remains somewhat glutinous, less so, if they are fresh and pure. 3 per cent. sulphur dissolved in camphine is said to be a good solvent. It dissolves in the fat and other volatile oils, but when dried, it remains in an adhesive state and destitute of elasticity; it is not soluble in oils of lavender, cloves, cinnamon, nor linseed, nor in Dippel's animal oil. It is soluble in 20 times its weight of bisulphuret of carbon, which leaves it in its original elastic state. It behaves in a singular manner with ammonia, which seems to have the power of bringing it into an emulsic state after months' contact; it may be then applied as a varnish, and recovers on drying its peculiar properties.

Dilute acids do not act upon caoutchouc. Sulphuric acid dissolves it after long digestion without forming tannin; when heat is applied, it is converted into a terebinthic mass. It is rapidly acted on by fuming nitric acid, nitric oxide being evolved. Muriatic acid does not affect it. It is not attacked by gases, such as chlorine, sulphurous, fluosilicic, but easily by nitrous vapors.

When heated to a temperature of about 248°, it melts, and on cooling, remains in a semifluid adhesive state, but when exposed to the air in thin layers it gradually acquires hardness.

When heated sufficiently in the air, it smokes, giving out an odor which is not disagreeable, then takes fire, burning with a strong yellow flame and much smoke. When pure caoutchouc is distilled, there passes off a large quantity of combustible gas, but neither carbonic acid nor ammonia; if impure it evolves all these. The chief product is caoutchucin or caoutchouc oil. The purest caoutchouc was found by Faraday to consist of 87.2 carbon and 12.8 hydrogen, which is nearly according to the formula C_8H_7 .

CAOUTCHOUC MANUFACTURE.

This department of industry, which had its birth but a few years since, has grown so rapidly and exhibited such a variety of novel, ingenious, and useful applications, within a short period of time, that it may already take high stand among the ancient mechanical arts, since in a vast number of instances it supersedes the use of woven textures, leather, &c. Its elasticity, resistance to wear and tare of surface, to chemical reagents, its closeness of texture, &c., are qualities which will insure its eminence, as soon as improved mechanism shall enable the manufacturer to throw it into any required form. We can now observe it replacing woven goods to a limited extent; we find it now made into almost every possible variety of leather, though far surpassing the latter in most of its qualities; it can be made into a paper; it can be made of any required thickness or thinness; it will receive white and colored grounds, on which more delicate lines of engraving are impressed than on any kind of paper; articles are made up from these materials with great ease and rapidly by simply cutting out and cementing pieces together more firmly than can be effected by the needle. Since this is but a meagre outline of the advantages which attend the elastic fabrics; what may we not hope from them, when mechanical and chemical forces shall have been more extensively applied to them than we witness at the present moment.

We distinguish two distinct kinds of caoutchouc, the common material and that composed according to Goodyear's process.

Common Gum Elastic. 1. The crude material, as imported in skinny shreds, fibrous balls, twisted concretions, cheese-like cakes, and irregular masses, is, more or less, impure, and sometimes fraudulently interstratified with earthy matter. It is cleansed by being cut into small pieces, and washed in warm water. It is now dried on iron trays, heated with steam, while being carefully stirred about to separate any remaining dirt, and is then passed through, between a pair of iron rolls, under a stream of water, whereby it gets a second washing, and becomes at the same time equalized by the separate pieces being blended together. The shreds and cuttings thus laminated, if still foul or heterogeneous, are thrown back into a kind of hopper over the rolls, set one-sixteenth of an inch apart, and passed several times through between them.

The large and thick tables of the gum are sliced into cakes for the stationer, and into sheets for making tapes and threads of caout

chouc, by an ingenious self-acting machine, in which a straight steel blade, with its edge slanting downward, is made to vibrate rapidly to and fro in a horizontal plane; while the cake of caoutchouc, clamped or embraced at each side between two strong iron bars, is slowly advanced against the blade by screw-work, like that of the slide rest of a lathe. In cutting caoutchouc by knives of every form, it is essential that either the blade or the incision be constantly moistened with water; for otherwise the tool would immediately stick fast. As the above straight vibrating knife slants obliquely downward, the sheet which it cuts off spontaneously turns up over the blade in proportion as it is detached from the bottom mass of the cake. The thicker slices are afterward cut by hand, with a wetted knife, into small parallelopipeds for the stationer, the sections being guided rectangularly by saw lines in a wooden frame. Slices may be cut off to almost any desired degree of thinness, by means of an adjusting screw—a mechanism that acts against a board which supports the bottom of the cake, and raises it by any aliquot part of an inch, the cutting-blade being caused to vibrate always in the same horizontal plane. These thin slices constitute what is called sheet-caoutchouc, and they serve tolerably for making tubes for pneumatic apparatus, and sheaths of every kind; since, if their two edges be cut obliquely with clean scissors, they may be made to coalesce, by gentle pressure, so intimately, that the line of junction cannot be discovered either by the eye, or by inflation of a bag or tube thus formed.

2. Sheets of caoutchouc, parts of rubber bags, are cut into continuous threads by highly ingenious machines. In using Westhead's machine, the bottom of a bottle of India rubber of good quality being selected, is cut off and flattened by heat and pressure into a nearly round cake of uniform thickness. This cake is made fast at its centre by a screw nut and washer to the end of a horizontal shaft, which may be made to revolve with any desired velocity by means of appropriate pulleys and bands, at the same time that the edge of the disc of caoutchouc is acted on by a circular knife of cast-steel, made to revolve 3000 times per minute, in a plane at right angles to that of the disc, and to advance upon its axis progressively, so as to pare off a continuous uniform tape or fillet from the circumference of the cake. During this cutting operation, the knife and caoutchouc are kept constantly moist with a slender stream of water. A succession of threads of any desired fineness is afterwards cut out of this fillet, by drawing it in a moist state through a guide slit, against the sharp edge of a revolving steel disc.

The body of the bottle of Indian rubber, and in general any hollow cylinder of caoutchouc, is cut into tapes, by being first forced upon a mandril of soft wood of such dimensions as to keep it equally distended. This mandril is then secured to the shaft of a lathe, which has one end formed into a fine-threaded screw, that works in a fixed nut, so as to traverse from right to left by its rotation. A circular disc of steel, kept moist, revolves upon a shaft parallel

to the preceding, at such a distance from it as to cut through the caoutchouc, so that, by the traverse movement of the mandril-shaft, the hollow cylinder is cut spirally into a continuous fillet of a breadth equal to the thickness of the side of the cylinder.

Threads of caoutchouc are readily pieced by paring the broken ends obliquely with scissors, and then pressing them together with clean fingers, taking care to admit no grease or moisture within the junction line. These threads must be deprived of their elasticity before they can be made subservient to any torsile or textile manufacture. Each thread is *inelasticated* individually in the act of reeling, by the tender boy or girl pressing it between his moist thumb and finger, so as to stretch it to at least eight times its natural length, while it is drawn rapidly through between them by the rotation of the power-driven reel. This extension is accompanied with condensation of the caoutchouc, and with very considerable disengagement of heat. The reels, after being completely filled with the thread, are laid aside for some days, more or fewer, according to the quality of the caoutchouc, the recomposed requiring a longer period than the bottle material. When thus rendered inelastic, it is wound off upon bobbins of various sizes, adapted to various sizes of braiding, or other machines, where it is to be clothed with cotton or other yarn.

In the process of making the ELASTIC TISSUES, the threads of caoutchouc being first of all deprived of their elasticity, are prepared for receiving a sheath upon the braiding-machine. For this purpose they are stretched by hand, in the act of winding upon the reel, to 7 or 8 times their natural length, and left two or three weeks in that state of tension upon the reels. Thread thus *inelasticated* has a greater specific gravity.

3. Water-Proof Fabrics. The parings, the waste of the kneading operations above described, and the coarsest qualities of imported caoutchouc, such as the inelastic lumps from Para, are worked up into varnish, wherewith two surfaces of cloth are cemented, so as to form a compound fabric, impervious to air and water. The caoutchouc is dissolved either in petroleum (coal-tar), naphtha, or oil of turpentine, by being triturated with either of the solvents in a close cast-iron vessel, with a stirring apparatus, moved by mechanical power. The heat generated during the attrition of the caoutchouc is sufficient to favor the solution, without the application of fuel in any way. Three days are required to complete the solution of one charge of the varnish materials. The proportion of the solvent oils varies with the object in view, being always much less in weight than the caoutchouc.

When the varnish is to be applied to very nice purposes, as bookbinding, &c., it must be rubbed into a homogeneous smooth paste, by putting it in a hopper, and letting it fall between a couple of parallel iron rolls, set almost in contact. At the end of the gallery, where the varnish is applied to cloth, the web which is to be smeared must be wound upon a beam, resembling in size and situation the cloth-beam of the weaver's loom. The piece is thence drawn up and stretched in a horizontal direc-

tion over a bar, like the breast-beam of a loom, whence it is extended in a somewhat slanting direction downward, and passed over the edge of a horizontal bar. Above this bar, and parallel to it, a steel-armed edge of wood is adjusted, so closely as to leave but a narrow slit for the passage of the varnish and the cloth. This horizontal slit may be widened or narrowed at pleasure by thumb-screws, which lower or raise the movable upper board. The caoutchouc paste being plastered thickly with a long spatula of wood upon the down-sloped part of the web, which lies between the breast-beam and the above-described slit, the cloth is then drawn through the slit by means of cords in a horizontal direction along the lowest rails of the gallery, whereby it gets uniformly besmeared. As soon as the whole web, consisting of about 40 yards, is thus coated with the viscid varnish, it is extended horizontally upon rollers, in the upper part of the gallery, and left for a day or two to dry. A second and third coat are then applied in succession. Two such webs, or pieces, are next cemented face to face, by passing them, at the instant of their being brought into contact, through between a pair of wooden rollers, care being taken by the operator to prevent the formation of any creases, or twisting of the two-fold web. The under one of the two pieces being intended for the lining, should be a couple of inches broader than the upper one, to insure the uniform covering of the latter, which is destined to form the outside of the garment. The double cloth is finally suspended in a well-ventilated stove-room, till it becomes dry, and nearly free from smell. The parings cut from the broader edges of the under piece, are reserved for cementing the seams of cloaks and other articles of dress. *Ure's Supplement.*

Metallic Gum Elastic Composition. The following specification and claim of Goodyear's Patent is taken from the Journal of the Franklin Institute, 3d ser. vol. ix. p. 89.

"My principal improvement consists in the combining of sulphur and white lead with India rubber, and in the submitting of the compound, thus formed, to the action of heat, at a regulated temperature; by which combination and exposure to heat it will be so far altered in its qualities as not to become softened by exposure to the solar rays, or of artificial heat, at a temperature below that to which it was submitted in its preparation, say to a heat of 270° of Fahrenheit's scale; nor will it be injuriously affected by exposure to cold; it will also resist the action of the expressed oils, and that, likewise, of spirits of turpentine, and of the other essential oils, at common temperatures, which oils are its usual solvents."

The compound may be formed of various proportions of the ingredients, but that which is deemed best consists of twenty-five parts of India rubber, five of sulphur, and seven of white lead—the India rubber having been previously dissolved in some of the essential oils, and the sulphur and white lead ground in the manner of preparing paint.

Claim.—"I do hereby declare that I do not claim the combining of sulphur with caoutchouc either in the proportions named, or in

any other, this combination having been the subject of a patent granted to me on the 24th day of February, 1839; but I do claim the combining of the said gum with sulphur, and with white lead, so as to form a triple compound, either in the proportions herein named, or in any other, within such limits as will produce a like result. And I will here remark, that although I have obtained the best result from the carbonate of lead, other salts of lead, or the oxides of that metal, may be substituted therefor, and will produce a good effect; I, therefore, under this head, claim the employment of either of the oxides, or salts of lead, in the place of the white lead, in the above-named compound. I also claim the formation of a fabric of the India rubber by interposing layers of cotton batting between those of the gum in the manner and for the purposes described. I likewise claim, in combination with the foregoing, the process of exposing the India rubber fabric to the action of a high degree of heat, such as is herein specified, by means of which my compound is effectually changed in its properties, so as to protect it from decomposition, or deterioration, by the action of those agents which have heretofore been found to produce that effect upon India rubber goods."

I have repeatedly experimented on this composition, which is a singular compound of sulphuret of lead with caoutchouc, and found it materially altered in some of its properties. It is *more perfectly elastic* than common caoutchouc, for after a long continued compression, or extension, it returns precisely to its former dimensions; it seems to possess greater tenacity, requiring a considerable force to produce rupture; it is *equally flexible*, or nearly so, in summer and winter temperatures, differing in this respect remarkably from common caoutchouc; it resists the action of the usual solvents of caoutchouc in an extraordinary degree, being insoluble in ether, and the essential oils, and scarcely affected by acids, excepting by oil of vitriol. The long-continued action of the essential oils renders it softer and brittle; but its original qualities may be more or less restored. It resists wear and tare of surface still more powerfully than common caoutchouc, for after a mail-bag composed of it had been dragged over many miles of a macadamized road, the iron staples and nails were worn nearly through, while the elastic material was scarcely abraded. The ease and rapidity with which various articles, such as harness, shoes, &c., &c., can be joined together by the simple use of a cement and subsequently rendered firm by the heating process, prove conclusively, when joined to the qualities above enumerated, that fibrous textures of cotton, &c., covered with this composition, will be substituted for the various kinds of leather, in many branches of the latter manufacture. Having employed various articles in ordinary dress and in chemical operations made of the composition, or of cloth covered with it, and having seen nearly all the applications enumerated below, I can subscribe to the following enumeration of qualities and applications by the patentee:

"Qualities. No degree of heat, without blaze,

can melt it; it remains unaltered in the torrid zone; heat, without blaze, more intense than 280° F., chars it like wood; it continues flexible in great degrees of cold, and even by the contact of ice is not stiffened; in durability it surpasses any other material applicable to similar uses; its elastic power is superior to that of common india rubber, and is retained unaffected by heat, cold, or continued stretching; of itself, or in combination with fabrics of cotton, or other material, it can be made of any desirable strength, with or without elasticity; it resists powerful chemical reagents; aqua fortis, sulphuric acid, essential and common oils, turpentine and other solvents, which destroy the native gum, wood, leather, and metals, produce no effect upon this composition, except that long continued immersion in strong aqua fortis, or sulphuric acid, chars it (see results of experiments above, *J. C. B.*); it possesses valuable medical qualities, being a substitute for oiled silk, furnishing hydrostatic beds, and a great variety of articles used in surgery; it, as well as the fabrics with which it is used in combination, can be washed in boiling water, with lime or lye, without injury; like other gum-elastic compositions, it is water-and-air-proof; it is not liable to be injured by rats, moths, or other vermin; it can be moulded or embossed like wax, and can be prepared in sheets of any thickness or thinness; it will take any color; it will take japan varnish, and equals in beauty patent leather, as it surpasses it in many other qualities; it takes impressions more delicately than the finest paper; it can be woven or braided; it can be napped, like broad-cloth or plush; it can be rendered perfectly tasteless, and inoffensive in point of odor; its contraction, after having been stretched in threads between two adhering thicknesses of cotton, silk, or other flexible material, shirs or corrugates the fabric in a new and beautiful manner, and renders it applicable to a variety of uses.

Applications. It is for many purposes a cheaper and better substitute for leather, cloth, and hair cloth, oiled cloth, oiled silk, paper, and parchment, while the shirred or corrugated goods are peculiar, and for many purposes unrivalled.

It can be economically and usefully employed in almost every article of external clothing, particularly where protection from cold and rain, or durability, is desired; in trimming carriages; for harness, of all kinds; in building, particularly for roofs and cisterns; in furniture (land and sea), particularly for carpets, printed floor-cloths, &c.; for firemen's dresses, for water hose; for the binding of books; as a substitute for paper and parchment, and for maps and charts; for the canvas and rigging of ships, supplying them also with compact boats, life preservers, rope and tarpaulins, and perhaps with sheathing and caulking materials; for belts and banding of machinery, and for smiths' bellows; for bags, bagging, compact casks, used in securing and transporting merchandise, dry or liquid; in many branches of the arts, as tubes for conveying various liquids, as vessels for containing them for evaporation, and for crystallization.

It is especially applicable to the wants of *Governments*, furnishing to the post-office the cheapest and best mail bag, and ships' letter bag, water-proof, more durable than rivetted leather, incapable of sinking when filled with papers, unalterable by climate; to the army, tents, tent carpets, tarpaulins, gun covers, knapsacks, blankets, cartridge cylinders, pontons, magazines, soldiers' dress and equipments, baggage wagon covers, and appurtenances; to the navy, canvas for sails, rigging boats, life preservers, buoys, fenders, gun covers, gun breaching, spring cables, probably sheathing and caulking materials, carpets, awnings, tarpaulins, cartridge cylinders, fire screens, tanks, holding fresh water for ballast, hose, buckets, magazines, water bags, provision bags, sailors' and mariners' dress and equipments, hammocks and hammock cloths, and bags.

The above-mentioned, are some of the qualities and uses of this composition. It is not pretended, that all the fabrics of this composition possess, alike, all the qualities, or are applicable to all the uses, before enumerated: each kind of fabric possesses those qualities which are desirable for the uses to which it should be applied. A cloth intended to sustain friction, would be different from a cloth designed to resist pulling or straining; and light, semi-transparent fabrics, suitable for printing upon, being finished by a peculiar process, do not possess, as they do not require, some of the qualities which are desirable in heavier goods. *Charles Goodyear.*

When we examine the above applications, in which a large number of details are omitted, and remember that they have been practically tested and found successful, and when we consider that still greater improvements will unquestionably be made, and more extended applications be devised, it cannot be thought presumption to predict that the Caoutchouc Manufacture is destined to compete in value and extent with any other branch of the useful arts.

CAOUTCHUCIN. Oil of Caoutchouc. Crude caoutchouc, cut into pieces, is subjected to distillation in iron or copper retorts, raising the temperature gradually to about 600°. A light yellow oil first passes over, followed by a darker brown oil, and charcoal, &c., remains in the retort. From the nitrogenous matter present in the crude gum, carbonate of ammonia often deposits in the neck of a glass retort. The amount of oil may be as high as 85 per cent. of spec. grav. 0.84 to 0.89. The crude oil is redistilled one or more times with water, a lighter colored oil being obtained at each successive rectification.

The purified oil is transparent, colorless, gradually changing in the air to brown, of a strong and not disagreeable odor, which may be diminished by chlorine or chloride of lime; spec. grav. = 0.68; it is volatile, its vapor being heavy and capable of decantation; its boiling point is 93°, but it gradually rises to 149°, proving that it is a compound of several oils.

It is composed according to the formula CH. Bouchardat obtained from it by distillation a more volatile oil, consisting of *EUPHIONE*, liquid

bicarburetted hydrogen, and *Caoutchen*, and a less volatile oil, *Hevëen*. Himly termed the oil passing over between 91° and 111° Faradayin, probably a mixture, and that passing over at 334° *Caoutchin*.

Use. Caoutchucin is an excellent solvent of caoutchouc, but in all probability not superior to pure camphine, and much more expensive. With a very minute quantity of caoutchouc dissolved in it, it constitutes an excellent cement for the gum itself, it being only necessary to brush a thin layer over the surfaces to be united, and to press them together, when in a few moments they are so firmly cemented as to constitute a single mass. It also dissolves the various resins, constituting an excellent varnish, superior to that made by camphine, for the latter is more subject to injury by keeping.

CAOUTCHIN. Prepared by rectifying caoutchucin, and catching the products passing over between 284° and 536° ; it is shaken with diluted sulphuric acid, as long as the latter is colored, washed with water and potassa, rapidly distilled with water, dried by chloride of calcium, repeatedly distilled, and the oil collected between 320° and 338° ; this oil is heated in a retort, to remove a volatile oil, and when the liquid attains 331° it is rapidly distilled, and only that oil received which passes over between 334° and 340° ; the oil thus redistilled is treated with dry chlorohydric acid gas, after some days the brown resinous deposit separated, the muriated oil dissolved in absolute alcohol, precipitated with dilute alcohol and treated with water and chloride of calcium. The muriate of caoutchin is distilled once or twice over caustic lime or baryta, dried by chloride of calcium and finally rectified over potassium.

It is a colorless, limpid liquid, with the odor of oil of orange, of a peculiar sharp-aromatic taste; spec. grav. at $61^{\circ} = 0.8423$; boils at 340° ; spec. grav. of vapor = 4461; is soluble in every proportion in absolute alcohol, the essential and fat oils, and in sulphuret of carbon. Formula, C_8H_4 . *Himly*.

CAOUTCHEN. Obtained by Bouchardat by distilling caoutchouc and catching the products in a series of cooled receivers, in the first of which was caoutchucin, and 2 others, cooled by snow and chloride of calcium, contained a yellowish liquid. When the distillate is cooled for several days eupione rises to the top as an oily liquid, and is separated; the residue is distilled at 50° , when liquid bicarburetted hydrogen passes over, and the liquid distilled off between 50° and 64° , exposed to a cooling mixture, congeals to a mass of white needles which are pressed rapidly between bibulous paper.

Thus obtained, it is a white opaque mass, of spec. grav. 0.65 at 28° , fusing at 50° to a limpid liquid, boiling at 58° , insoluble in water, soluble in absolute alcohol and ether. It is not acted on by alkalies and behaves to sulphuric acid like liquid bicarbohydrogen. Form. CH, or a multiple of it. *Bouchardat*.

Hevëen is another oily liquid, obtained by Bouchardat, which boiled at 599° , and had the same composition.

It appears from the experiments of Himly, Bouchardat and Gregory, that caoutchouc yields

several oily liquids, some of which are composed according to the formula CH or a multiple of it, and others according to C_5H_4 , which is that of CAMPHEN. The most volatile have the low spec. grav. 0.654.

CAPACITY. May be employed in its common acceptation, expressive of content, such as the capacity of a vessel, or the quantity of matter it may contain, but the term is also used in heat and affinity. In the former it is synonymous with *specific heat* (see HEAT). In affinity it denotes the power of an acid to become saturated by a base in order to form a neutral salt. Berzelius expresses the saturating capacity of an acid by the quantity of oxygen in the base, which is neutralized by 100 pts. of the dry acid. Thus 100 pts. dry sulphuric acid neutralizes just so much of any base, that the latter contains 19.96 of oxygen; hence 19.96 is the saturating capacity of sulphuric acid.

CAPILLARY ATTRACTION. *Phys.* That variety of adhesion exhibited by the rise of liquids or gases in tubes of fine bore, or in porous substances, such as charcoal, sponge, &c. See ADHESION AND ABSORPTION.

CAPNOMOR. (From *καπνός*, smoke, and *μορφή*, a part, existing in the smoke of organic bodies.) It occurs with creasote, picamar, and pittacall, in the heavy oil of tar. *Prep.* Digest the oil, deprived of acetic acid by carbonate of potassa, with a solution of potassa, of spec. grav. 1.20; heat the alkaline liquor slowly, and allow it to boil for a short time, then to cool slowly, and decompose it by dilute sulphuric acid in slight excess. Distil the dark-brown oil in a retort with a little potassa, but not to dryness; dissolve the transparent pale oil in a solution of potassa, of spec. grav. 1.16, heat it as before, and treat it with dilute sulphuric acid; these processes repeated several times with weaker potassa solutions. The oil is mixed with waters, saturated with ammonia, and distilled, catching the last portions, which are capnomor.

Prop. Capnomor is a transparent, colorless, oily liquid, with the odor of rum, at first tasteless, subsequently acrid, refracting light like creasote; spec. grav. at $68^{\circ} = 0.9775$; it boils at 365° , at 28.25 in., *Bar.*; does not congeal at -6° ; is insoluble in water and in potassa, soluble in alcohol, ether, and eupione; dissolves caoutchouc, especially when heated, and may be the cause of tar dissolving caoutchouc. It acts as an acid with vegetable bases, and as a base with sulphuric acid. It dissolves many vegetable substances, fats, resins, coloring matters, &c. It is distinguished from creasote and picamar by its taste, insolubility in alkali, and by dissolving caoutchouc; from eupione by spec. grav. and boiling point, by its smoke when burning, its solubility in sulphuric acid, &c. It has not been analyzed.

CAPORCIANITE. It is a grayish-red zeolite, occurring in radiated masses, and was found by Savi, near the village of Monti Catini, in Tuscany. According to Anderson, it consists of silica 52.8, alumina 21.7, peroxide of iron 0.1, lime 11.3, magnesia 0.4, potash 1.1 soda 0.2, water 13.1 = 100.7. (*Dana*.) According to this analysis, its formula is $3CaO, 2SiO_3 + 3(Al_2O_3, 2SiO_3) + 9HO$, which is the

same as Chabazite, Analcime, &c., with a different content of water.

CAPRIC ACID. *Ger.* Caprinsäure. Its preparation see under **BUTYRIC ACID**.

Capric acid resembles caprylic acid in its properties. The baryta salt crystallizes from hot solutions in minute fatty needles and scales, and on spontaneous evaporation likewise in scales, arranged in dendritic groups; it is very difficult of solution, is anhydrous, and not affected by exposure to the air. Formula, $C_{20}H_{40}O_2 + HO$. *Chem. Gaz.* ii. p. 380.

CAPROIC ACID. *Ger.* Capronsäure. Its preparation see under **BUTYRIC ACID**.

The barytic salt crystallizes in long silky needles, aggregated into bundles; it is anhydrous, and undergoes no change by exposure to the air. Form. $C_{12}H_{22}O_2 + BaO$.

The silver salt is prepared in the same manner as butyrate of silver, but is far more difficult of solution. It is not crystallizable, and consists of $C_{12}H_{22}O_2 + AgO$.

Caproic Ether is prepared in the same way as the butyrate; it separates more readily, boils at 248° , has a stronger taste and smell, but is not so agreeable. Form. $C_{16}H_{32}O_4 = C_4H_8O + C_{12}H_{24}O_3$. *Chem. Gaz.* ii. p. 379.

CAPRYLLIC ACID. Its preparation see under **BUTYRIC ACID**.

At the ordinary temperature it forms a smeary mass; below 50° it crystallizes in needles, which are of difficult solution in water, have an acid and acrid taste, and a peculiar, disagreeable odor. Formula, $C_{16}H_{32}O_2 + HO$. The baryta salt separates from hot solutions in brilliant laminæ, but on spontaneous evaporation in white granules. It is anhydrous, is not affected by exposure to the air, does not fuse at 212° , and is very sparingly soluble in water. The silver salt is almost insoluble. The lead salt is very sparingly soluble in water, and fuses at 212° .

CAPSICIN. The fruit of the *Capsicum annuum*, analyzed by Maurach, Bucholz, and Braconnot, presents such different results, that it should be re-examined. The 4 per cent. of acrid soft resin of Bucholz, and the 1.9 per cent. acrid oil of Braconnot probably contain the same active principle capsinin, but not in a pure state. Witting seems to have obtained it purer.

Capsicin. Obtained by digesting the alcoholic extract in ether, and evaporating the ethereal solution. It is a thick liquid, or soft resin, of a yellowish-red or reddish-brown color, which becomes very fluid when heated, and, at a higher temperature, is dissipated in fumes. Half a grain of it, volatilized in a large room, causes all who respire the air of the room to cough and sneeze. By exposure to air and light it solidifies; it is decolorized by chlorine; it is slightly soluble in water and in vinegar; but very much so in alcohol, ether, oil of turpentine, and the caustic alkalis; with baryta it forms a solid acrid combination. Witting describes it as pulverulent, crystallizable, permanent in air, insoluble in cold water and ether, but little in hot water and in alcohol; forming crystallizable salts with acetic, nitric, and sulphuric acid, which are soluble in water, and decomposed by alkalies, with the precipitation of capsinin.

CARAMEL. *Tech.* Cane sugar melts at 356° into a viscid colorless, liquid, which, on cooling, forms a transparent, amorphous mass (barley-sugar). At a temperature somewhat higher, it becomes brown; at from 410° to 430° it swells up, and is converted into a black porous mass, having a high lustre, like anthracite, called by Peligot *Caramel*. In this operation water alone is expelled, with a minute trace of empyreumatic oil and acetic acid. The caramel of commerce contains a variable proportion of sugar, from which, and from certain bitter compounds which are present, it is purified, by dissolving it in water and adding alcohol, which precipitates the caramel in a state of purity, retaining the foreign matters in solution.

Pure caramel is a black or brownish black powder; dissolves readily in water, giving it a fine sepia tint; its solution has no taste, and no action on vegetable colors; is not susceptible of fermentation, and is insoluble in alcohol. Its solution precipitates the salts of baryta and the basic salts of lead. The composition of the barytic precipitate is variable; it contains from 20 to 21 per cent. of baryta.

When sugar is still more strongly heated, the caramel loses an additional quantity of water, and forms an insoluble compound. At a still higher temperature inflammable gases are given off, and a bulky coal is left, difficult of combustion.

According to Peligot, caramel has the same composition as cane sugar in its compound with oxide of lead, that is, $C_{12}H_{20}O_9$. Crystallized cane sugar, therefore, to form caramel, loses 2 eq. of water. Grape sugar produces the same substance when similarly treated, but it fuses at 212° , giving off 9 per cent. water. *Liebig.*

It is employed to color wines, vinegar, and confections, in which it is a harmless adulteration (see **ACETIC ACID**).

CARAWAY. *Tech. Phar.* The oil of caraway (*Ger.* Kümmelöl) obtained by distilling the bruised seed of *Carum Carui* with water (yielding about 5 per cent.), is pale yellow, becoming brownish, of a penetrating aromatic odor and taste, reddens litmus, absorbs iodine without heat; absorbs chlorohydric gas, which it evolves by boiling with water; spec. grav. = 0.938, boils at 401° , when an oil passes over with little oxygen, and a boiling point of 379° ; another more fixed oil containing much more oxygen boils at 442° . It is probable that the former oil, if pure, would be a carbohydrogen analogous to **CUMEN**; the latter may be **COMINOLE**. (*Völkel.*) When distilled with caustic potassa it yields a carbohydrogen, *Caruen* = $C_{10}H_8$, and the residue mixed with water separates into a brown resin and a brown alkaline solution; the latter saturated with acid and distilled yields an acrid oil, *Caruacrole*. (*Schweizer.*)

Oil of caraway is employed to impart flavor, and in medicine. The tincture of the seed or oil is drunk in Germany, *Kümmelliqueur*.

CARBAMID. See *Chlorocarbonic acid* under **CARBON**.

CARBAZOTIC ACID. Formed by the action of nitric acid on **INDIGO**.

CARBOLIC ACID. *Chem. Prep.* Mix 6 pts.

of oil of coal-tar with 1 pt. lime and 25 pts. water, as in preparing KYANOLE, decompose the lime-salt by muriatic acid, wash the separated brown oil water, distil off $\frac{1}{3}$, redistil the latter several times with water, adding a little potassa the last time. A milky mixture of carbolic acid and water passes over first, followed by pure carbolic acid.

Prop. An oily liquid, refracting light powerfully, often crystallizing in long needles, with a penetrating odor resembling Castoreum, a sharp burning taste: spec. grav. = 1.062 at 68°; boils at 387°; burns with a yellow smoky flame; soluble in 31 pts. water at 68°, miscible in all proportions with alcohol and ether; dissolves sulphur; is decomposed by chlorine, iodine, sulphuric and nitric acids. Its peculiar reaction is, that a piece of pine-wood dipped into it or its aqueous solution, and then into chlorohydric acid, becomes dark blue on drying, nor does chlorine change the color.

Its alkaline salts are colorless, soluble, crystallizable; it forms neutral, acid and basic salts with lime and oxide of lead. The acid dissolves indigo at 212°, and the solution bleaches by air and light in a few days; it dissolves rosin, copal, and a little amber; it precipitates gelatin, coagulates albumen, preserves animal matters powerfully from putrefaction, contracting and hardening them. (*Runge.*) There appears to be a close resemblance between this acid and CREASOTE. See the products of distillation of COAL.

CARBON. *Ger.* Kohlenstoff; *Fr.* Carbone.

Sym. C. Eq. 6. The importance to organic chemistry of an exact knowledge of the combining weight of carbon has led to extended investigations by different chemists of its compounds, and with varying results. Biot and Arago's early experiments led to the number 75.33, those of Berzelius to 76.438. In 1838 Dumas thought it should be reduced to 75.9 or 76; in 1840, Dumas and Stass, by weighing the purest carbons and the carbonic acid they yielded, obtained as an average of 14 experiments 75.005, max. 75.125, min. 74.875, the carbons being natural and artificial graphite, and the diamond. Baron v. Wrede, 1840, by showing that carbonic acid did not follow Mariotte's law, made it above 75.4 and below 76. Liebig and Redtenbacher in 1840 obtained as an average of 20 experiments on the acetate, malate, tartrate, and racemate of silver 75.735, max. 76.111, min. 75.346; they farther calculated from Berzelius's former analyses of the two last salts 75.741. In 1841, v. Wrede, by a comparison of spec. gravs. of oxygen, carbonic acid, and oxide, with Rudberg's coefficient of expansion, obtained 75.13, with Magnus and Regnault's coefficient 75.12. Erdmann and Marchand, 1841, obtained in 9 experiments, 5 with diamond, 3 with natural, and 1 with artificial graphite, 75.0544. Mitscherlich calculated it from the analysis of naphthalin at 75.1. Reviewing these, it may be assumed to be over 75; probably the best conclusion for the present is, that it is 75.12 on the oxygen, and 6.01 or 6.02 on the hydrogen scale. The present work, being of a practical character, it is assumed to be 6, without presenting it as the exact number.

History. Carbon, under the form of charcoal, known from the earliest times. Paracelsus and Van Helmont recognised carbonic acid as evolved by burning limestone and by fermentation, but this gas was more particularly examined by Hales, Black, Priestley, and Bergmann, and its composition determined by Lavoisier. Lassonne, Priestley, and Woodhouse discovered carbonic oxide, which others proved to contain only carbon and oxygen.

Preparation, &c. It occurs in nature crystallized in 2 forms, the DIAMOND and GRAPHITE; less pure and amorphous, ANTHRACITE and the various kinds of COAL. Among artificial forms are:

1. *Artificial Graphite*, formed in blast furnaces, when a white iron passes into gray metal, precipitating laminæ of graphite. To purify this and the native graphite, ignite it powdered with potassa, wash with water, boil it in nitromuriatic acid, and heat it to a white heat in dry chlorine for many hours. The presence of iron in graphite is accidental.

2. *Charcoal*, obtained from LAMPBLACK, purified by potassa; obtained by strongly igniting an organic substance, such as pure sugar, containing neither nitrogen nor ashes; obtained by the decomposition of illuminating gas in gas retorts, as an accidental product, *gas-carbon* especially depositing where the retort is fissured. See also CHARCOAL, BONEBLACK.

Properties. Dimorphous (diamond and graphite), colorless and colored (diamond), brownish yellow in glass colored by charcoal, (!) black and opaque (graphite and charcoals), transparent, of a peculiar lustre, refracting light powerfully, not conducting electricity (diamond), with a bright metallic lustre, conducting electricity (graphite, the surface of gas-carbon, and often common charcoal); hardness = 10 (diamond), sometimes = 6 (charcoal, gas-carbon), generally soft (charcoal, graphite); spec. grav. = 3.5 (diamond), = 2.14—2.27 (graphite), = 1.7—1.9 (gas-carbon), charcoal is often very light from its porous character. Carbon is tasteless, inodorous, one of the most infusible and fixed substances; doubt still prevails over the nature of the globules of carbon, carried over from the positive to the negative pole of the deflagrator in the experiments of Silliman and Hare. It is extremely difficult to account for the different properties of the varieties of carbon, their relations to crystalline form, to electricity, &c.; some assume that it is due to the position of atoms, the diamond belonging to the regular, graphite to the hexagonal system, while charcoal is amorphous; Döbereiner terms graphite a metal carbonium.

Carbon is insoluble in all solvents without change; it is disseminated in glass with a yellow, red, or brownish color. It combines with some of the metals, forming *carburets*, with hydrogen, nitrogen, sulphur, chlorine, &c.; it is one of the principal constituents of all organic substances. It may be said to surpass all other bodies whatever in its affinity for oxygen at a high temperature; and being infusible, easily got rid of by combustion, and forming compounds with oxygen which escape as gas, this body is more suitable than any other substance to effect the reduction of metallic oxides,

that is, to deprive them of their oxygen, and to produce from them the metal with the properties which characterize it.

Analysis. Carbon is usually determined in the state of carbonic acid. For the method pursued, see ANALYSIS of *Organic Substances*, with the apparatus, on pl. I.

Oxygen. 1. *Carbonic acid.* Syn. Fixed air, mephitic air; *Ger.* Kohlensäure, older names were Luftsäure, Kreidesäure; *Fr.* Acide carbonique, ou mephitique. It occurs in the air, about 0.05 of one per cent. in volume (see *ATMOSPHERE*); is ejected from volcanoes; issues in caves, cellars, &c., especially in limestone districts, the Grotto del Cane yielding over 200,000 lbs. per annum; in mineral springs called carbonated waters; in sea-water especially and other waters; extensively diffused in limestone, as carbonate of lime and magnesia; combined with other metallic oxides.

It is formed by the combustion of the diamond, graphite, coals, carbonic oxide, and organic substances in the air or in oxygen; by the respiration of animals; by the chemical action of nitric or sulphuric acids on carbon; by common fermentation, and putrefaction of organic matters; during various transformations and decompositions of organic bodies.

Prep. By pouring dilute chlorohydric or sulphuric acid over chalk, marble, limestone in a Woulfe's bottle, retort, or the apparatus represented, p. 174, fig. 23, under ANALYSIS; or if it be required dry in the apparatus, fig. 24, p. 176, without the tube *ef*; or in the self-generating reservoir, using pieces of limestone instead of zinc, see *HYDROGEN*. On a larger scale, it may be prepared by burning charcoal or coke, and washing the gas, if necessary, with an acid solution of copper or lead to remove sulphuretted hydrogen.

Prop. Carbonic acid is, at ordinary pressures, a transparent and colorless gas, exciting a pungent sensation in the nostrils, with a weak, but distinct acid, and slightly pungent taste; spec. grav. = 1.525; its power of refracting light (air = 1) is 1.526, (*Dulong*); its action upon vegetable blues is feeble, communicating to the infusion or paper of litmus a distinct reddish color, but if the infusion or paper be left in the air, the carbonic acid speedily escapes, and the blue color returns. No animal can breathe this gas, even when considerably diluted. No combustible will burn in it, even when much diluted, for if a candle be let down into a mixture of 9 vols. air and 1 vol. carbonic acid, it is extinguished; such a mixture may be breathed for a short time without great inconvenience. Water absorbs its own bulk of this gas, even when reduced by compression to one-half or

one-third its usual bulk; *soda* or *mineral* water, is water impregnated with about twice its volume of carbonic acid gas, hence its effervescence or briskness when the pressure is removed. The briskness of beer, champagne, &c., is due to the existence of carbonic acid in them, in a compressed state. A certain portion of this gas passed into a tube filled with lime or barytic water produces milkiness. This gas was liquefied by Mr. Faraday, whose method has been followed by Thilorier in an apparatus by which the liquid acid is procured in large quantity. It consists of two similar cylindrical vessels of strong sheet-iron, calculated to resist a bursting pressure of 60 atmospheres, in one of which several pounds of bicarbonate of soda are decomposed at once by an equivalent quantity of sulphuric acid. The gas confined within this generating vessel is afterwards allowed to communicate with the second cylinder or condenser, by means of a copper tube and stopcock of nice construction; and the charge is repeated several times in succession, till two or three pints of the liquid acid are collected in the receiver. When this liquid is allowed to escape from the receiver by a small jet, a portion of it is frozen by its own evaporation, and forms a white soft mass, like snow, which may be handled and does not evaporate very rapidly, owing to its low conducting power, although its temperature cannot be more than -148° . With a little ether the solid acid forms a semifluid mass, by means of which mercury can be frozen in considerable quantity. The spec. grav. of the liquid is 0.83 at 32° ; it dilates remarkably from heat, its expansion being four times greater than that of air, 20 volumes of the liquid at 32° becoming 29 at 86° , and its density varying from 0.9 to 0.6 as its temperature rises from -4° to 86° . It mixes in all proportions with ether, alcohol, naphtha, oil of turpentine, and bisulphuret of carbon, but is insoluble in water and fat oils. Its compound with alcohol may be frozen, and melts at -135° , which is the lowest point fixed with accuracy in the descending scale of temperature. The following are the results of careful experiments upon the elasticity of its vapor at different temperatures. *Addams.*

Elastic force of Liquid Carbonic acid.

Temperature.	Pounds per square inch.	Atmospheres of 15 pounds each.
0°	280	18.1
10	300	20
30	398	26.5
32	413	27.6
50	520	34.7
100	935	62.3
150	1496	99.7, <i>Graham.</i>

Composition:		<i>Dumas and Stass.</i>		<i>T. Saussure.</i>		<i>Tennant.</i>	<i>Allen and Pep.</i>
C	6	27.27	27.27	27.04 to 27.38		28	28.6
2 O	16	72.73	72.73	72.96 " 72.62		72	71.4
<u>CO₂</u>	<u>22</u>	<u>100</u>	<u>100</u>	<u>100</u>	<u>100</u>	<u>100</u>	<u>100</u>
	Vol.	Spec. grav.				Vol.	Spec. grav.
Carbon-vapor.....	1	0.4160		Carbonic oxide.....	1.0		0.9706
Oxygen.....	1	1.1092		Oxygen.....	0.5		0.5546
Carbonic acid	1	1.5252, or		Carbonic acid	1.0		1.5252.

$$(CO_2 = 75.12 + 2 \cdot 100 = 275.12, \text{ Berzelius.})$$

It is decomposed by a succession of electric sparks, especially when hydrogen or some metals are present; by heating with potassium, sodium, phosphorus, and boron.

Carbonates. Carbonic acid forms neutral, basic, and acid salts; colorless with colorless oxides; all the alkaline are soluble; the acid alkalino-earthly and a few others are soluble; all other carbonates are insoluble. The carbonates lose all or nearly all their acid at a red heat, except the neutral alkaline salts. This acid is one of the feeblest, hence its neutral alkaline salts exhibit alkaline reaction, hence also the carbonates are decomposed by all free acids soluble in water, (with the exception of hydrocyanic and hydrosulphuric,) the carbonic acid escaping with effervescence, as a colorless and almost inodorous gas. Lime and barytic water produce, with carbonic acid or soluble carbonates, white precipitates of neutral carbonate of lime or baryta, if with free carbonic acid, the reagent should be employed in excess. The precipitates formed dissolve in acids, with effervescence, and are not precipitated again by ammonia; after boiling, a solution of carbonate of soda containing 1 pt. carbonic acid to 40 or 80,000 pts. water, is clouded by barytic water, 1 to 20,000 by lime water. Chloride of calcium and chloride of barium yield with neutral alkaline carbonates immediately, and with bicarbonates only on boiling, precipitates of carbonate of lime or of baryta; they yield no precipitate with free carbonic acid. To remove carbonic acid from air or other gaseous mixtures, instead of caustic alkali or lime-water, the dry hydrate of lime may be mixed intimately with an equal weight of Glauber's salt, in fine powder; and this mixture in a stratum of not more than an inch in thickness intercepts carbonic acid most completely, and may rise in temperature to above 200° from the rapid absorption of the gas. It is quite possible to respire through a cushion of that thickness, filled with this mixture, and such an article might be found useful by parties entering an atmosphere overcharged with carbonic acid, like that of a coal mine after the occurrence of an explosion of fire damp. *Graham.*

Uses, &c. Carbonic acid, forced by compression into water contained in large vessels of tinned copper, is employed as an agreeable, sparkling beverage, (soda or mineral water,) usually by mingling it with variously flavored syrups. Where the vessels are not kept well tinned, a trace of copper will be dissolved, and imparts a metallic after-taste to the water; its presence may be known by evaporating a $\frac{1}{2}$ pint of the water to a small bulk, adding a few drops of pure sulphuric, muriatic, or nitric acid, and then caustic ammonia in excess, when a blue color indicates copper. Carbonic acid derived from burning coals is also employed in precipitating subacetate of lead to form white-lead.

Where carbonic acid has accumulated in wells, cellars, &c., its presence may be ascertained by letting down a lighted taper into it, when, if not extinguished, the air may be breathed safely for a short time. To remove

it, throw down dry slacked lime, or pass a considerable quantity of water into it, or raise and depress an inverted umbrella repeatedly in it in order to dilute it largely with air.

2. Chlorocarbonic acid. Syn. Phosgene gas, acide chloroxycarbonique. *Prep.* 1. Introduce equal volumes of dry carbonic oxide and chlorine into an exhausted glass flask; expose the mixture to sunshine for a few minutes until the color of the chlorine disappears, and the volume of the mixture diminishes one half. 2. Pass carbonic oxide over ignited chloride of lead or silver. *Prop.* A colorless gas, with a strong odor, more disagreeable and suffocating than chlorine, and affects the eyes with tears; reddens vegetable blues; tin, zinc, antimony, or arsenic, heated in it, decompose it, forming chlorides and setting free the carbonic oxide; water decomposes it into muriatic and carbonic acids; refracting power = 3.936; (air = 1;) spec. grav. = 3.425. Alcohol absorbs 12 times, chloride of arsenic 10 times its volume of the gas, and the chloride of sulphur also absorbs it; it forms with ammoniacal gas a white compound. Formula, CO, Cl , containing 71.66 per cent. chlorine, or C Cl_2 , CO_2 , but C Cl_2 is unknown. Dry ammonia and chlorocarbonic acid gases condense to a white, crystalline solid, which is a mixture of sal-ammoniac and carbamid, neutral, volatile, having a sharp taste, and deliquescent in the air; $2\text{NH}_3 + \text{CO, Cl} = \text{CO, NH}_2 + \text{NH}_4\text{Cl}$. It is soluble in water, not precipitable by salts of baryta or lime; strong inorganic acids decompose it into ammonia and carbonic acid, thus, $\text{CO, NH}_2 + \text{SO}_3, \text{HO} + \text{HO} = \text{NH}_4\text{O, SO}_3 + \text{CO}_2$.

3. Carbonic oxide. Ger. Kohlenoxyd. It is formed by the combustion of fuel with an insufficient supply of air, by heating an alkaline or earthy carbonate with charcoal or iron, by the decomposition of many organic substances. *Prep.* 1. By heating a mixture of oxide of zinc, iron, lead, or copper with charcoal in an iron or glass vessel to redness. 2. By heating carbonate of lime, baryta, or strontia with charcoal or iron filings, pretty strongly, we obtain very pure carbonic oxide, mixed, however, with a good deal of carbonic acid gas, which is easily removed by washing the gas with milk of lime. 3. Heat in a retort or gas bottle a mixture of concentrated sulphuric acid and binoxalate of potassa or oxalic acid, $\text{C}_2\text{O}_3 = \text{CO} + \text{CO}_2$. Caustic potassa or milk of lime removes the carbonic acid from any of the above gases, leaving the carbonic oxide pure. *Prop.* Colorless, destitute of taste or smell; spec. grav. = 1.57 (air = 1). It produces no change on vegetable blues, does not unite with acids or bases; water absorbs $\frac{1}{56}$ th to $\frac{1}{16}$ th of its volume; no animal can breathe it, and it is more poisonous than carbonic acid; it burns with a beautiful blue flame, giving out but little light; a mixture of 2 vols. of this gas and 1 vol. of air explodes by an electric spark, or with a red hot wire; 2 vols. carbonic oxide + 1 vol. oxygen, exploded over mercury, give 2 vols. carbonic acid gas.

CARBON.

Composition:

			Vol.	Spec. grav.
C	6	42.86	1.0	0.4160
O	8	57.14	0.5	0.5546
CO	14	100	1.5	0.9706

(C = $75.12 \div 100 = 75.12$, Berz.)

Sulphur. 1. *Bisulphuret of Carbon*. Sulpho-carbonic acid; *Ger.* Schwefelkohlenstoff. *Prep.* 1. From a mixture of sulphur and charcoal, the sulphur distills off without combination. Sulphur either as vapor, or fused or in solid pieces, is brought in contact with ignited charcoal; the carbon being contained in a porcelain tube or retort, in a vessel of graphite or a thick iron flask. Probably the best arrangement is a strong iron flask with an inclined tube entering near the bottom, and provided with a stop-cock, through which pieces of sulphur are let down from time to time upon the ignited pieces of charcoal with which the flask is filled; a broad, sheet-iron tube passing out from the top conducts the vapors into a sheet-iron receiver cooled by ice.

2. By distilling charcoal with iron or copper pyrites, or crude antimony. Sulphuret of carbon is purified from excess of sulphur by careful distillation; a very slow distillation yields fine crystals of sulphur; from water by distilling with chloride of calcium; from sulphuretted hydrogen by shaking with white lead.

Prop. It is a transparent and colorless liquid; taste acid, pungent, and somewhat aromatic; odor nauseous and fœtid; spec. grav. 1.272, or 1.265; refractive power = 5.179 (air = 1); expansive force at $63.5^\circ = 7.36$ in. mercury; boils between 105° and 114° , does not congeal at -60° ; it is extremely volatile, producing a great degree of cold, by evaporation; spec. grav. of vapor = 2634.5; it is scarcely soluble in water, but readily in alcohol and ether, the latter taking up 3 times its bulk; it readily unites with chloride of nitrogen, preventing it from detonating, when it comes in contact with oils or phosphorus. It takes fire in the open air at 680° , burning with a blue flame; its vapor detonates violently, when mixed with oxygen, by the electric spark, the products being sulphurous and carbonic acids, or carbonic oxide, with too little oxygen. It is decomposed by cold oil of vitriol into carbon and sulphur; by hypochlorous acid into carbonic, sulphuric, and muriatic acids, and chlorine; by ignited earths or oxides of manganese, iron, and tin into metallic sulphurets and other products; by heated potassium, iron, or copper, probably forming a simple sulphuret of carbon with the metallic sulphuret; under water, exposed to the air it gradually changes into sulphuric and carbonic acids. It dissolves gradually in the fixed alkalies, forming an alkaline carbonate and sulphocarbonate or carbosulphohydrate; with ammonia it forms slowly carbosulphohydrate and cyanosulphohydrate of ammonia. It mixes with liquid carbonic acid, chloride of sulphur and of nitrogen; dissolves sulphur, and 8 or more times its weight of phosphorus, forming a liquid of very high refracting power, iodine with a rich violet color, bromine; it dissolves or mixes with alcohol, ether, fat, and

CARBON.

volatile oils, resin, &c. Its behavior to chlorine, see 4, below.

2. *Solid Sulphuret of Carbon*. Remains with the charcoal after forming bisulphuret of carbon, or after washing salt-peter out of gunpowder. It has not been minutely studied.

3. *Sulphocarbonydic acid*. *Rothsäure*, *Zeise*; *Kohlenschwefelwasserstoffsäure*, *Berz.* Bisulphuret of carbon combines readily with the alkaline sulphurets in solution. Saturate alcohol with ammoniacal gas, and dissolve in it bisulphuret of carbon, carefully excluding the air; sulphocarbonate of sulphuret of ammonium deposits as a crystalline powder; which is washed with alcohol, then with ether, treated with somewhat dilute chlorohydric acid, then immediately diluted with water, and the aqueous liquid poured off from the brown oily acid. It is a reddish brown, transparent, oily liquid, heavier than water, precipitating salts of lead red, of copper reddish brown, of mercuric oxide yellowish. It combines with oxides, expelling carbonic acid. Form. $\text{HCS}_3 = \text{HS} + \text{CS}_2$.

Sulphocarbonates. Formed by mingling alkaline sulphurets with 1, caustic or carbonated fixed alkali with 3, or precipitating metallic solutions by alkaline sulphocarbonates. The alkaline are soluble, most of the others insoluble; the former have a sharp, cooling, and hepatic taste; the solutions are yellowish, the dry salts yellow, red, brown, black; they are easily decomposed.

4. *Sulphochloride of Carbon*. When a mixture of dry chlorine and bisulphuret of carbon is passed through an ignited porcelain-tube filled with fragments of porcelain, it is wholly resolved into a mixture of chloride of sulphur and perchloride of carbon. When sulphuret of carbon is conveyed into a flask filled with dried chlorine, and left to stand for some weeks well-closed, a dark yellow liquid is formed, which contains chloride of sulphur and the sulphochloride of carbon. The chloride of sulphur is decomposed by treatment with water, and the sulphochloride may be obtained pure by repeated distillation with water and magnesia. To prepare it, allow sulphuret of carbon to remain for a long time in a closed vessel containing a mixture for liberating chlorine; it is frequently shaken, and subsequently distilled. It is a yellow, oily, acrid-smelling liquid of 1.46 spec. grav., which does not mix with water; boils at about 158° , is neither altered by water nor by acids, (not even by fuming nitric acid,) but is decomposed by caustic potassa with the formation of carbonate of potassa, sulphuret of potassium, and the separation of perchloride of carbon. *Kolbe*.

Halogens. 1. *Subchloride of Carbon*. Obtained accidentally, and first examined by Faraday and R. Philips. Prepared by Regnault by passing chloride of carbon, 2, repeatedly through a red hot tube. *Prop.* White, silky prisms, tasteless, with a peculiar odor; insoluble in water; not acted on by sulphuric, nitric, or muriatic acids, nor by alkaline solutions; dissolves in alcohol, ether, hot oil of terpentine, from which it is deposited in needles on cooling; melts, boils, and sublimes at about 300° ; burns with a greenish blue flame; decomposed by potassium, which burns vividly

in its vapor, depositing carbon. Form. C_4Cl_2 , or C_2Cl .

2. *Chloride of C. Protochloride*. Formed by Faraday by passing sesquichloride, 3, through a red-hot tube filled with fragments of glass, and by careful and repeated distillation. *Prop.* A limpid, colorless liquid; spec. grav. = 1.5526; refracting power = 1.4875; burns with bright yellow light, and much smoke, when held in flame, exhaling fumes of muriatic acid; does not congeal at zero; boils at 248° ; at a red heat undergoes partial decomposition; is not soluble in water; dissolves in alcohol, ether, the volatile and fixed oils; is not acted on by alkaline solutions, nor by nitric, muriatic, nor sulphuric acids; oxygen decomposes it at high temperatures; chlorine dissolves in it, and when exposed to sunlight is converted into sesquichloride of carbon; it dissolves iodine, forming a red solution; sulphur and phosphorus dissolve it; its action on metals and metallic oxides is very similar to that of sesquichloride. The spec. grav. of its vapor = 5748 (5820, *Regnault*). Form. C_4Cl_2 , or C_2Cl_2 .

3. *Sesquichloride of C. Perchloride*. Prepared by exposing the oil of olefiant gas or *Dutch liquid* (see carburetted HYDROGEN) to the action of an excess of chlorine in sunlight, when the liquid is transformed into crystals of the sesquichloride, while chlorohydric acid is evolved, $C_4H_4Cl_2 + Cl_8 = C_4Cl_6 + 4HCl$. *Prop.* Transparent, colorless crystals, six-sided prisms of the right rhombic system, with little taste, an aromatic odor; spec. grav. = 2; refractive power high; very friable; volatilizes slowly at common temperatures, fuses at 320° , boils at 360° ; in the flame of a spirit lamp it burns with a red flame, emitting much smoke, in oxygen, with a brilliant light; insoluble in water, dissolves readily in alcohol, more in hot than in cold, precipitable by water, much more soluble in ether, soluble in volatile and fixed oils; acids and alkalis act on it with little energy; it melts with sulphur or phosphorus without change, but at a high temperature, chloride of sulphur or phosphorus and chloride of carbon are formed. Most of the metals decompose it at a high temperature, charcoal being deposited, and chlorides formed; with metallic oxides, different results are obtained, according to the oxides, producing chlorides and carbonic acid, or mixtures of carbonic acid and carbonic oxide. Spec. grav. of vapor 8201.9, (8157, *Regn.*). Form. C_4Cl_6 , or C_2Cl_3 .

4. *Bichloride of C.* Formed by exposing chloroform (see chloride of FORMYL) or Marsh gas (carburetted HYDROGEN) to an excess of chlorine in sunlight, when the bichloride and muriatic acid are formed. A liquid of spec. grav. 1.6; boils at 192° ; spec. grav. of vapor = 5328 (5302, *Regn.*). Formula, C_4Cl_8 , or C_2Cl_4 .

The above compounds of chlorine and carbon are more closely allied to organic than inorganic substances.

CARBONATE OF BISMUTH. *Min.* See BISMUTITE.

CARBONATE OF LANTHANUM. *Min.* Thin 4-sided scales of a grayish white color; gives moisture in a closed tube; dissolves in acids with effervescence; consists mainly of carbonate of lanthanum, with traces of protox-

ide of cerium. It is found at Bastnäs in Sweden, coating cerite.

CARBUNCLE. *Min.* See GARNET.

CARDAMOM. *Phar.* Plants of the order Zingiberaceæ; among which are GINGER, TURMERIC, Amomum, Eleteria, &c. Trommsdorff's analysis of *Eleteria Cardamomum* gave: essential oil 4.6, fixed oil 10.4, a salt of potassa (malate?) combined with a coloring matter 2.5, fecula 3.0, nitrogenous mucilage with phosphate of lime 1.8, yellow coloring matter 0.4, and woody fibre 77.3.

The essential oil is obtained by distilling the seeds with water; it is colorless, has an agreeable odor, and a strong, aromatic, burning taste; spec. grav. = 0.943; is very soluble in alcohol, ether, oils, and acetic acid, insoluble in potash-lye; by keeping, it becomes yellow, viscid, and loses its peculiar taste and smell; it then detonates with iodine, and takes fire in contact with concentrated nitric acid. On this oil depends the odor, flavor, and aromatic qualities of the seeds. Its composition is $C_{10}H_8$, like camphen.

The fixed oil is soluble in alcohol, ether, and the oils, both fixed and volatile, and has some analogy to castor oil. *Pereira*.

CARMINE. *Chem. Tech.* See COCHENILLE.

CARNELIAN. *Min.* See QUARTZ.

CAROTIN. A principle in the root of *Daucus carota* (common carrot). Carrot juice has a brick-red color, taste sweetish, coagulates under 212° , and when dried amounts to 0.629 of the juice, is composed of 0.435 vegetable albumen, 0.10 fat oil, 0.034 carotin, and 0.06 of earthy phosphates; the distilled juice gives off $\frac{57.00}{100}$ of its weight of volatile oil, which is colorless, has a caroty smell, a strong taste; spec. grav. = 0.8863; is little soluble in water, very soluble in alcohol and ether.

Carotin is extracted by ether from the coagulated juice, the ether evaporated and the residue treated with caustic ammonia, whereby the oil is saponified and dissolved; redissolve the residue in ether, and add absol. alcohol. The carotin crystallizes by evaporation in small needles, which are purified by bibulous paper to absorb the oil, or retreated with ammonia. *Prop.* Small ruby-red needles or scales, with neither taste nor smell, neutral; heat softens, but does not melt it, it is not volatile, but burns without residue; is soluble in anhydrous alcohol and ether, when mixed with fixed or volatile oils, in which it is readily soluble; the yellow solutions are rendered colorless by the solar ray. *Wackenroder*.

CARPHOLITE, CARPHOSIDERITE. See KARPOLITE and KARPHSIDERITE.

CARRAGEENIN. A principle in *Chondrus crispus*, Irish Moss. Herberger's analysis gave:

Vegetable jelly.....	79.1
Mucus.....	9.5
Two resins.....	0.7
Fatty matter and free acids.....	} traces.
Chlorides of sodium or calcium, and sulphate of potassa.....	
Iodine or bromine.....	

The mucilaginous matter (*vegetable jelly* or *pectin*) may be a peculiar substance. It is soluble in boiling water, and its solution forms a precipitate with subacetate of lead and silicate

CARTHAMUS.

of potassa, and, if sufficiently concentrated, gelatinizes on cooling. It is distinguished from ordinary gum by its aqueous solution not producing a precipitate on the addition of alcohol; from starch, by its not assuming a blue color with tincture of iodine; from animal jelly, by tincture of nutgalls causing no precipitate; from pectin, by acetate of lead not throwing down any thing; as well as by no mucic acid being formed by the action of nitric acid.

CARTHAMUS. The flowers of *Carthamus tinctorius*, Safflower, contain several coloring matters, *Carthamin*, *Carthamein*, and a yellow color which has not been minutely studied.

Carthamin. *Prep.* To isolate it, exhaust the flowers with water, to remove the yellow color; place them in contact with water rendered slightly alkaline by carbonate of soda; precipitate by hydrate of lead; decompose this salt, well-washed, by an excess of sulphuretted hydrogen, and filter; the yellow liquid furnishes white acicular crystals of pure carthamin. Small white prismatic needles, of a slightly bitter taste, somewhat soluble in alcohol, less so in water; exposed to the air, it acquires a faint yellow color; dilute sulphuric acid dissolves it—when concentrated, it blackens it; hydrochloric and nitric acids produce no color, but dissolve it by a gentle heat. When introduced into a bell-glass full of mercury, with oxygen and alkalis it immediately becomes yellow, then rose-red, being changed into carthamein; ammonia changes the white carthamin to a rose color, with greater difficulty than caustic or carbonated potassa or soda; acetate of lead precipitates carthamin as a white lake, which, by lengthened contact with the atmosphere, becomes yellow, and then rose-colored.

Carthamein dissolves readily in alkalis, and by neutralizing the solution with citric acid, red flakes, similar to the carthamin prepared by the ordinary processes, are deposited, which are carthamein. Pure carthamin gave the formula, $C_{26}H_9O_5$, eq. = 2562.32; the crystals afforded 8.29 per cent. water; 2 atoms = 8.07. Carthamein gave $C_{26}H_9O_7$, and modified carthamein $C_{24}H_7O_7$. It is evident, therefore, that carthamin, on becoming colored, absorbs 2 atoms of oxygen from the atmosphere, $C_{26}H_9O_5 + O_2 = C_{26}H_9O_7$; but under the influence of solar light and by lengthened contact with the air, it parts with 2 atoms carbon and 2 atoms hydrogen, which combine with 6 atoms oxygen, and are given off as carbonic acid and water, as is shown by the following equation:— $C_{26}H_9O_7 + O_6 = C_{24}H_7O_7 + 2CO_2 + 2HO$. *Preisser in Chem. Gaz.* ii. 351.

CARTILAGE. See **CHONDRIUM**.

CARUEN, CARUACROLE. Distil oil of caraway with hydrate of phosphoric acid until the peculiar odor of the oil disappears: caruen passes over, caruacrole remains. Rectify the caruen over potassa, until colorless; it amounts to $\frac{1}{3}$ of the oil. It is a thin liquid, with a pleasant odor and taste, lighter than water, in which it is slightly soluble, very soluble in alcohol and ether, burns with a bright smoky flame, becomes resinous in the air, boils at 343° ; spec. grav. of vapor = 5175; decomposed by sulphuric and nitric acids, and by chlorine, the last forming a viscid yellow compound; com-

CARYOPHILLIN.

bines with dry muriatic acid, forming a muriate of caruen, analogous to muriate of camphen, with the composition, $C_{10}H_8$, HCl. Caruen may be also prepared from the oil by distillation over potassa, or any body which decomposes the oxy-oil into a substance with a higher boiling point. Form. $C_{10}H_8$.

Caruacrole. By fractioning the redistillation of the residue in preparing caruen, taking only the middle portions, caruacrole is obtained pure. It is a colorless, thick liquid, heavier than water, in which it is slightly soluble, very soluble in alcohol, ether, and potassa lye, of a peculiar disagreeable odor, sharp biting taste, boils at 450° , decomposed by nitric acid, potassa, and potassium, the last evolving hydrogen. Formula, $C_{40}H_{28}O_3$, *Schweizer*. See **CARAWAY**.

CARYOPHILLIN. *Chem.* Cloves are the unexpanded flower of the *Caryophyllus aromaticus* (*Eugenia caryophyllata*). Their analysis by Trommsdorff gave volatile oil 18, almost tasteless resin 6, peculiar kind of tannin 13, difficultly soluble extractive with tannin 4, gum 13, woody fibre 28, and water 18. Their volatile oil consists of two oils, a light carbohydrogen, and a heavy oil, caryophillic acid, beside which, the clove contains caryophillin and eugenin.

Oil of Cloves. Obtained by submitting cloves, with water, to repeated distillation; they yield from 17 to 22 per cent. of volatile oil, which is a mixture of the two oils. When carefully and recently prepared it is colorless or light-yellow, but by keeping becomes brownish-red; has a hot acrid taste, the odor of cloves, is soluble in alcohol, ether, concentrated acetic acid, and the fixed oils; spec. grav. 1.034 to 1.055. To separate the two oils mix it with potassa-lye and distil; a light oil passes over, while a compound of the heavy oil and potassa remains in the retort, and, by distillation with phosphoric or sulphuric acid, gives out the heavy oil.

Light Oil. Colorless; spec. grav. 0.918; incapable of combining with bases, but absorbs chlorohydric acid gas without yielding a crystalline compound; consists of $C_{10}H_8$; isomeric with camphen.

Caryophillic acid. Syn. Eugenic acid, Clove acid, Heavy oil of cloves. Obtained as above, the acid is a colorless, oily liquid, of the odor and taste of cloves, reddens litmus; spec. grav. = 1.079; boils at 469° ; neutralizes alkalis perfectly, forming crystallizable soluble salts with potassa and baryta, which become alkaline by evaporation; an iron salt added to an alkaline solution of the acid produces a blue or reddish tint; nitric acid reddens the heavy oil. Formula, $C_{24}H_{10}O_5$; *Ettling and Bäckmann*; Dumas's first analysis gave $C_{20}H_{13}O_5$, his second, $C_{20}H_{12}O_5$; but the composition is doubtful.

Caryophillin. Described by Lodibert, examined by Bonastre and by Dumas. It is extracted from cloves by boiling alcohol, the Molucca cloves yielding the largest quantity, those of Bourbon less, Cayenne cloves none. It is a silky, crystalline, odorless, tasteless, fusible, and volatile substance; insoluble in water, soluble in alcohol and ether; slightly so in caustic alkalis, reddened by sulphuric acid.

CASCARILLA.

According to Dumas, its formula is $C_{20}H_{16}O_2$; or the same as that of camphor.

Eugenin. Found by Bonastre, and obtained from the distilled water of cloves; thin, white, pearly scales, which become yellow by keeping; very soluble in alcohol and ether; has the odor and taste of cloves, but weaker, and is reddened by nitric acid. According to Dumas, its composition is $C_{20}H_{12}O_4$, or $C_{24}H_{15}O_5$, which is that of caryophyllin acid.

CASCARILLA. *Phar.* The bark of the *Croton Eleuteria*, or *Cascarilla*, analyzed by Trommsdorff, gave volatile oil 1.6, bitter resin 15.1, gum and bitter matter with trace of chloride of potassium 18.7, woody fibre 65.6. The volatile oil possesses the odor and taste of the bark; spec. grav. = 0.938 to 0.909; color variable, greenish, yellow, or blue; consists of two oils, one boiling at 344° , and which contains no oxygen (its formula probably being $C_{10}H_8$); the other less volatile and oxygenated. Nitric acid converts it into a yellow, pleasant smelling resin. By distillation with water the bark yields about $\frac{1}{20}$ th of its weight of this oil.

The resin consists of two, one acid, the other neutral, separable by tincture of acetate of copper from the tincture of the bark. *Cascarillin* has been found in the bark, but not minutely studied.

CASEIN. *Chem. Tech. Physiol.* Syn. Legumin; *Ger.* Käsestoff. Casein exists in the milk of the mammalia, and constitutes the greater part of cheese made from skimmed milk. Legumin was found by Braconnot in the seeds of the *Leguminosa*, who showed its analogy to casein; their identity was proved by Liebig, who showed the similarity of a solution of legumin with skimmed milk.

Prep. From milk. 1. Precipitate skimmed milk with dilute sulphuric acid, wash the precipitate, digest it with carbonate of baryta, filter and evaporate gently; or precipitate skimmed milk with alcohol, boil the pressed precipitate with alcohol, then with ether, until all fat is removed, dissolve in warm water, filter, and evaporate. (*Berz.*) 2. Add a little dilute acetic acid to skim-milk, warm it to 140° or 149° , stir up the precipitate with water 20 times, and express it each time in linen, treat the residue with boiling alcohol, until the latter is not clouded by water, and dry it. It gave 3.83 per cent. ashes consisting of phosphate of lime. (*Mulder.*) 3. Some dilute sulphuric acid is added to fresh milk and warmed, when the cohering casein is separated from the greater portion of the enclosed whey by kneading in frequently-renewed pure water, after which it is treated in the cold with a concentrated solution of carbonate of soda, until the whole of the casein has dissolved to a turbid syrupy liquid. This solution, containing an excess of soda, is allowed to stand at 70° Fah. in shallow vessels until the butter has separated, the greater portion of which may be skimmed off, and the liquid beneath separated by a syphon. The solution of casein in soda is thrown down by dilute sulphuric acid, and purified by kneading as before, and the same solution in soda, and precipitation with acid, is repeated three times, when a considerable portion of the adherent acid has been removed by washing, from 60 to

CASEIN.

70 times the weight of the casein of pure water is poured over it in a dish, and the whole heated to boiling, after which it is left in quiet. After treating the casein from 15 to 20 times with water, to remove the last traces of fat and water, the casein is boiled with absolute alcohol, and then with anhydrous ether, until these solvents leave no residue on evaporation. (*Rochleder in Lieb. Ann.* xlv. 253.)

From seed. When peas, beans, or lentils are softened in cold water, then ground with that fluid, and the mass further diluted, and strained through a fine sieve, there passes through a solution of casein in which starch is suspended. When the starch has settled, the supernatant liquid is a solution of casein, which is always, like milk, turbid, partly from suspended fat, partly from the gradual action of the air on the dissolved casein, lactic acid being slowly formed, which causes a gradual separation. This solution has all the characters of skimmed milk; it is coagulated by acids, not by heat, and forms a pellicle when heated. It also coagulates after long standing from the formation of lactic acid; and, when the coagulum putrefies, the odor is exactly that of putrid cheese. (*Liebig.*)

Prop. Casein, after purification, is nearly insoluble in water, what is called soluble casein being a compound of it with soda, potassa, or lime. Casein dissolves with ease, and in very considerable quantity, in carbonated and caustic alkalies, from which solutions it is precipitated by all acids, with the exception of the carbonic. The precipitate is soluble in a large excess of acid. The solutions of casein in dilute acids are milky, and cannot be obtained perfectly clear by filtration; they froth on shaking like solutions of soap, and become covered on evaporation with a transparent pellicle, which is as frequently renewed as it is removed. When a solution of a barytic salt is added to a solution of casein in an acid, an opakeness is produced from an insoluble combination of the casein with baryta, even when the quantity of casein is very small. Casein also destroys the alkaline reaction of phosphate of soda, forming a slimy, frothing liquid. These properties show that the coagulation of the soluble casein by acids is nothing more than a separation of the casein resulting from the combination of the acid with the base of the casein compound. They also point out the cause of solutions of potash preventing coagulation when added in very small quantity to milk, and explain why the slightest causes, especially in the warm months of summer, are able to produce a coagulation of the milk, as only the smallest quantity of lactic acid requires to be formed to neutralize the minute traces of soda, which are able to retain in a state of solution an enormous quantity of casein. (*Rochleder.*)

Both the casein thrown down from its solution in alkalies by acids, as well as that precipitated from its solution in acids by carbonate of soda, reddens litmus paper, and retains this property even after desiccation at 293° , but does not communicate it to the water in which it is boiled.

While casein forms soluble alkaline com-

pounds, its combinations with earths and metallic oxides are generally insoluble, and its solutions are precipitable by all salts excepting alkaline. Caséin is somewhat soluble in alcohol, which solubility is due to the presence of alkali; Scherer found in the coagulum of sour milk, after boiling it with alcohol and ether, 2 per cent. ashes, while the caséin from the alcoholic solution yielded 7.9 per cent.

Aqueous solutions of caséin, form ammoniacal products (see *Apösepidin* below). It swells up in sulphuric acid, becoming translucent, and with much water forms a hard insoluble compound containing 8.4 per cent. acid. Nitric acid produces with it Xanthoproteic acid. See **PROTEIN**. Strong muriatic acid becomes colored indigo-blue by it, as well as by albumen and fibrin.

Pure caséin is unknown, for it always contains mineral matter, and hence leaves ash by combustion, which consists of phosphate and carbonate of magnesia and lime, and generally alkali. Mulder found 0.36 per cent. sulphur in it. Neglecting the inorganic constituents, its formula is $C_{48}H_{36}N_6O_{14}$, or, according to Mulder, this being the formula of protein, caséin is represented by 10 Pr + S. See **ALBUMIN**, **FIBRIN**, and **PROTEIN**.

Apösepidin. Oxide of Caseum, Proust. 3 pts. of well-drained smear-cheese (sour, coagulated skim-milk) is mixed with 4 pts. water and stood for a month at 68° to 77°, drained through a woollen cloth, the liquid heated, filtered, evaporated to a syrup, and the reddish mass treated with cold alcohol of 37° Beaumé. What dissolves is Proust's *caseate of ammonia*, the insoluble impure apösepidin; the latter several times dissolved in boiling water, is filtered through bone-black, and evaporated.

It is white, inodorous, bitter to the taste, sublimates partly unaltered in a tube, from a hot aqueous solution separates in dendritic crystals, easily putrefies in solution, scarcely soluble in cold, more in hot alcohol, precipitable by subacetate of lead and infusion of galls, decomposed by nitric, but not by muriatic acid. It has not been analyzed. Mulder regards apösepidin as impure **LEUCIN**.

CASSIA. *Phar. Tech.* See **CINNAMON** and **SENNA**.

CASTING. *Tech. Ger.* Giessen; *Fr.* Fondre. One of the arts of copying, by which solids of almost every possible form may be imitated, or made, by means of a liquid, which hardens in the mould or on the body to be imitated. The substances employed are various: metals are brought to fusion and cast into a mould, as in the manufacture of cannon, bells, medals, &c., (see **BRONZE** and **BRASS**), of type and stereotype, (see these,) of various objects, utensils, machinery (see **IRON**); gypsum, (Plaster of Paris,) boiled and mixed with water into a paste, porcelain and pottery slip, &c., are cast in moulds, in which the former hardens spontaneously, the latter dries, and is then burned hard (see **PORCELAIN** and sulphate of lime under **CALCIUM**). Fused sulphur is also employed for taking casts.

The nature of the mould varies with the casting material; for all substances it must resist the action of the liquid, and not yield in any

point; for metals, it is composed of a more infusible metal, or of sand, with a mixture of clay, hair, &c., for binding the sand; for gypsum and slip, it may be of gypsum, or the former is usually cast directly on the statue, medal, or other object to be copied.

CASTOR OIL. *Phar. Ger.* Ricinusöl; *Fr.* Huile de ricin. An oil obtained from the seeds of the *Ricinus communis*, which is cultivated in the East and West Indies, in the United States, &c. It is obtained by boiling the seeds with water or by expression. In the United States the cleansed seeds are gently heated in a shallow iron reservoir, to render the oil liquid for easy expression, and then compressed in a powerful screw-press, by which a whitish oily liquid is obtained, which is boiled with water in clean iron boilers, and the impurities skimmed off as they rise to the surface. The water dissolves the mucilage and starch, and the heat coagulates the albumen, which forms a whitish layer between the oil and water. The clear oil is now removed, and boiled with a minute portion of water until aqueous vapors cease to arise: by this process an acrid volatile matter is got rid of. Good seeds yield about 25 per cent. of oil. *Wood and Bache's Dispens.*

Prop. Pure castor oil is a thick, viscid, colorless fluid, with little or no odor, and a mild though somewhat nauseous taste, followed by a slight sense of acrimony; is often tinged with yellow, and has an unpleasant smell; rarely of a brownish color, and hot acrid taste. It does not readily congeal by cold; when exposed to the air it slowly thickens, without becoming opaque, and ranks among the drying oils; it is heavier than most other fixed oils, and is soluble in all proportions in cold absolute alcohol; weaker alcohol, of spec. grav. 0.8425, takes up about three-fifths of its weight; adulterations with other fixed oils may thus be detected, as the latter are but slightly soluble in this fluid; it is also soluble in sulphuric ether. *Wood and Bache.*

By distillation a volatile oil is obtained analogous to acrolein; by saponification, ricinic, ricinoleic, and stearic acids; by nitrous acid, palmin and palmic acid; by nitric acid, **OENANTHIC ACID**.

Volatile oil. It is separated by washing, and by distillation with water. It is limpid and colorless, has a peculiar odor, an acrid taste; spec. grav. = 0.815; is soluble in alcohol and ether, but insoluble in a solution of potassa; by long-continued exposure to a temperature of 23° F. it becomes crystalline.

Stearic acid (Margaritic, Ricinostearic). Crystallizes in pearly scales; is distinguished from ricinic and ricinoleic by its high fusing point, by its partial decomposition when submitted to distillation, and by the insolubility of the salt of magnesia in alcohol. The crystallized hydrate consists of $C_{35}H_{51}O_6$. *Laurent.*

Ricinic acid. Crystalline, solid at ordinary temperatures, and fusible at 72° F. Its crystallized hydrate consists of $C_{35}H_{51}O_5$. *Laurent.*

Ricinoleic acid (*Elaëodid*) is a yellow-colored liquid at 32° F.; but at many degrees below it becomes crystalline.

Palmin. Castor oil treated with nitrous acid produces a new fat. Palmin is white, at first

waxy, then resinous; fuses at 151° , is very soluble in alcohol and in ether, is easily saponified, glycerin being separated, and palmate of potassa being formed. When the soap is dissolved in water, and mixed with muriatic acid, palmitic acid separates on cooling, in a crystalline mass.

Palmitic acid. White, silky needles, soluble in all proportions in alcohol and ether, in 5 pts. alcohol of 0.915, reddens litmus paper strongly, combines with bases, and decomposes the carbonates, fuses at 122° .

Palmate of soda is obtained by mixing palmitic acid with a solution of carbonate of soda, evaporating to dryness, and digesting the residue in alcohol, which only dissolves the palmate; when treated with a great deal of water, a bipalmate is formed. The salts are generally soluble in hot alcohol. A current of sulphurous acid gas, when passed through castor oil, converts it into a solid mass, which seems to be palmin, and which, when saponified, yields palmitic acid.

CASTOR. *Phar.* Castoreum; *Ger.* Bibergeil. Sacs between the anus and external genitals of both sexes of the beaver (*Castor fiber*). Two kinds are distinguished, the American and Russian. The following analyses of castor are by Brandes, 1, the American, 2, the Russian: Pereira thinks the amount of inorganic matter too great in the analysis of 1.

	1.	2.
Volatile oil.....	1.00	2.0
Resin.....	13.85	58.6
Cholesterin.....	—	1.2
Castorin.....	0.33	2.5
Albumen.....	0.05	1.6
Gelatin.....	—	10.4
Osmazome.....	0.20	2.4
Matter soluble in alcohol..	—	1.6
Carbonate of lime.....	33.62	2.6
Other salts.....	2.82	2.4
Mucus.....	2.30	—
Animal matter, like horn..	2.30	—
Membrane.....	20.00	3.0
Moisture and loss.....	22.83	11.7
	99.30	100

Essential oil of Castor. Obtained by distilling the same water several times with fresh portions of castor; pale yellow, has the odor of castor, with an acrid, bitter taste.

Castorin. Castoreum Camphor. Obtained by boiling castor in alcohol; the castorin deposits when the liquor cools. A crystalline, fatty, non-saponifiable substance, fusible, and in the liquid state floats on water; when pure it is white; soluble in ether and boiling alcohol. By long ebullition with nitric acid, it is converted into a yellow crystallizable acid, *castoric acid*. The super-castorate of ammonia is crystallizable, and forms white precipitates with the salts of silver, lead, and protoxide of iron, and green precipitates with the salts of copper. Castorin is allied to *Cholesterin*.

Resin. Dark brown, has an acrid and bitter taste, a slight odor of castor, is insoluble in pure ether, dissolves readily in alcohol, from which water precipitates it.

CATALYSIS. The action of *contact* or *presence*. Berzelius and Mitscherlich understand by catalysis, the decomposition produced by a solid or liquid, in another body, without itself undergoing a chemical change, or at least without assuming any of the constituents of the body decomposed. Thus many metals and metallic oxides dropped into binoxide of hydrogen, produce a rapid evolution of oxygen, excepting that oxide of silver loses its oxygen at the same time; sulphuric acid converts starch, &c., into grape-sugar, causing it to assume the elements of water, while the acid itself remains unaltered and uncombined. Some of the phenomena have been explained in other ways, but others again have not received any other explanation. We may therefore employ the term as expressive of such phenomena, until it shall have been shown to be incorrect, or until they may be explained in some more satisfactory manner. See *Conditions of Affinity* and *Contact*.

CATECHU. *Syn.* Terra Japonica. *Fr.* Catechu. An extract derived from 1, *Arcea catechu* or *Catechu Palm*, which contains tannin (chiefly), gallic acid, (?) gluten, red insoluble matter, fixed oil, gum, oxalate of lime, lignin, &c. (*Morin*). 2. Gambir-catechu, from the *Uncaria Gambier*. It contains tannin 36—40 per cent., gummy matter, tannic deposit, fibre $2\frac{1}{2}$ per cent. (*Nees v. Esenbeck*). 3. Cutch from the *Acacia* or *Mimosa Catechu*. There are probably other sources of catechu. The quantities of tannin it yields varies from 30 to 55 per cent., but no complete analysis has been latterly made. The main constituent in catechu is a species of tannin, catechutannic acid, which dissolves in cold water, while a small amount of catechin remains; the latter by distillation forms pyrocatechin, and by contact of alkali, japonic and rubinic acids. It contains no gallic acid, for catechu yields no pyrogallac acid by distillation. (*Stenhouse*.) In tanning with catechu a considerable quantity of catechin was found on the leather. *Cooper*.

Catechutannic acid. It is prepared in the same manner as tannic acid in a displacement apparatus, or the filtered aqueous extract is treated with a little sulphuric acid and filtered, then with sulphuric acid as long as it precipitates, washed with dilute acid, pressed in paper, boiled with water, filtered, the red solution treated with an excess of carbonate of lead, filtered, and evaporated in vacuo. Its properties agree in general with those of tannic acid, excepting that it precipitates persalts of iron greenish, is not precipitated by tartar emetic, its compound with sulphuric acid is less permanent, and more soluble, its potassa salt is more soluble, and forms by evaporation a dark brown, translucent extract. The salts are so easily decomposed that it is almost impossible to obtain them in a dry state. Pelouze's analysis of the acid leads to the formula, $C_{18}H_9O_8$.

Catechin. *Syn.* Catechuic, Tanningenic acid. Obtained by repeated maceration of gambir-catechu with cold water, boiling the residue with water and passing the impure deposit after resolution in hot water through animal charcoal previously treated with muriatic acid, or the redissolved deposit is precipitated by sub-

acetate of lead, decomposed by sulphuretted hydrogen, the acid separated from the sulphuret of lead by hot water, when it is deposited white, as the solution cools. It is rapidly pressed between paper, and dried, in vacuo, over sulphuric acid. It is a very feeble acid, not expelling the carbonic; combines with ammonia; is soluble in 1100 pts. cold, and 2—3 pts. boiling water, in 5—6 cold, and 2—3 hot alcohol, in 120 cold, and 7—8 pts. hot ether; soluble in dilute acids unchanged, decomposed by strong acids; it fuses at 422° , it produces no precipitate in lime, baryta, or their salts; throws down a lead salt-white, perchloride of iron deep green, protosulphate of iron bluish green to black, acetate of copper brown and black, silver salts and chloride of gold brown, chloride of platinum whitish yellow; but the precipitations are not immediate, and are always accompanied by partial decomposition of the catechin, and a reduction of the three last metals. Formula of the crystallized dried at 212° , $C_{20}H_{10}O_9$, of the fused $C_{20}H_8O_9$, or $C_{20}H_6O_9$.

Pyrocatechin. When distilled catechin yields this substance, beside empyreumatic oil; when purified by sublimation it forms white scales, of a bitter, burning taste, empyreumatic odor, fuses at 259° , exhibits to reagents a close analogy to catechin, and its green color with perchloride of iron is an exceeding delicate test of iron.

Japonic acid. Catechin is digested with caustic potassa, in contact with the air, when it absorbs oxygen, and changes first to red, then to black, forming japonic acid. The alkaline liquor is treated with acetic acid, evaporated almost to dryness, and digested in alcohol, which leaves superjaponate of potassa; this is repeatedly digested in alcohol, dissolved in water, and muriatic acid added in small excess, whereby japonic acid precipitates.

Prop. Black, dissolves slightly, if at all, in cold water; its aqueous solution reddens litmus; insoluble in alcohol. The japonates do not crystallize, but dry into hard masses, the salt of potassa is obtained by boiling the acid in a concentrated state with caustic potassa, and removing the excess of potassa by alcohol. With chlorides of barium, calcium, and aluminum it gives bulky black precipitates, not soluble in dilute nitric acid; with sulphate of copper, a dark green, with nitrate of silver, a black precipitate. Formula of the acid, $C_{24}H_8O_8 + 2HO$, of the silver-salt, $C_{24}H_8O_8 + AgO$. *Svanberg.*

Rubinic acid. By dissolving catechin in carbonate of potassa, and leaving the solution exposed to the air without heat, it becomes red, and dries into a hard, uncrystalline mass, which is rubinate with carbonate of potassa. If heat be applied, the salt is converted into japonate of potassa. The rubinate is reduced to a very fine powder, dissolved in water, saturated with acetic acid, the solution rapidly filtered, and mixed with strong alcohol, when the rubinate of potassa precipitates and is washed with alcohol. Rubinate of potassa throws down the earthy and metallic salts of a red color, the precipitates generally redissolving during washing. Form. of the acid in the silver salt, $C_{18}H_6O_9$. *Svanberg.*

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Uses of Catechu. It is employed in tanning, dyeing, and calico-printing, especially in the two last operations. It forms the basis of a series of brown and olive colors, as shown by the following reaction of 1 pt. catechu in 10 pts. water.

The color itself is..... reddish brown.
 Acids..... lighten it.
 Alkalies..... darken it.
 Copperas..... olive brown precip.
 Persulphate of iron olive green do.
 Blue vitriol..... yellowish brown do.
 Alum..... brightens the liquid.
 Pernitrate of iron olive green precipitate
 Nitrate of copper..... yellowish brown do.
 Nitrate of lead..... salmon do.
 Proto-nitrate of mercury yellowish brown do.
 Muriate of alumina brownish yellow.
 Muriates of tin do. do.
 Corrosive sublimate... light chocolate do.
 Acetate of alumina..... brightens the liquid.
 Verdigris..... copious brown precip.
 Acetate of lead salmon colored do.
 Bichromate of potassa.. copious brown do.

It may be employed as a light brown on cotton with any other preparation, but for darker tints, it must also be passed through iron solution; a rich brown is attained by passing cotton-yarn through catechu and sulphate of copper dissolved, and afterwards through a lukewarm bath of bichromate of potassa.

CATHARTIN. *Phar.* The active principle in several species of *Cassia*, from Egypt, Syria, India, United States, &c. Lassaigne and Feneulle's analysis of the Senna leaves of Alexandria gives cathartin, yellow coloring matter, volatile oil, fixed oil, albumen, mucus, malic acid, malate and tartrate of lime, acetate of potassa, mineral salts, lignin, &c.

The volatile oil, obtained by submitting the leaves to distillation with water, has a nauseous odor and taste.

Cathartin. Yellowish red, uncrystallizable, with a peculiar odor, a bitter nauseous taste; very soluble in water and alcohol, insoluble in ether; attracts water from the air; its aqueous solution is precipitated by infusion of galls and subacetate of lead; the persulphate of iron and alkalies deepen the color of the infusion; chlorine decolorizes it; iodine, acetate of lead, gelatine, and tartar emetic cause no precipitates with it; yielding no ammonia by distillation, it contains no nitrogen; it does not combine with acids. It is a strong purgative and cathartic. According to Herlein, cathartin has an acid, bitter, and unpleasant taste, its aqueous infusion tests acid, it does not possess any purgative character, leaves alkaline ashes by ignition, and is of a complex constitution.

CATLINITE. *Min.* A somewhat hardened clay formation, on the Côteau des Prairies in the Sioux country, highly valued and extensively used by the Indians for making smoking pipes. It has a delicate brick-red color, may be easily cut in any direction, but splits more readily in the plane of deposition, has an unctuous touch, and is susceptible of a fine polish. $H. = 1.5-2$. $G. = 2.54$. Analysis by C. T. Jackson:

CATS EYE.

Silica.....	48.2
Alumina.....	28.2
Magnesia.....	6.0
Lime.....	2.6
Peroxide of iron.....	5.0
Oxide of manganese.....	0.6
Water.....	8.4
	99.0

CATS EYE. *Min.* See QUARTZ.

CAUSTIC. *Phar.* The term is mainly applied to nitrate of SILVER and to Potassa. *Tech.* Caustic lye is generally applied in the arts to a solution of potassa or soda employed in the manufacture of SOAP, and the term caustic lime to quick-lime. *Chem.* The chemist applies the term caustic to the hydrated alkalies, potassa, soda, or ammonia, or to the hydrated and anhydrous alkaline earths, baryta, strontia, lime, and magnesia.

CAVIAR. The salted roe of several species of Acipenser. John's analysis of it gave soluble albumen 6.2, buttery fat 4.3, common salt 6.7, phosphate of lime 0.5, coagulated albumen and membrane 24.3, water 58.0.

CAVOLINITE. *Min.* See NEPHELINE.

CAWK. *Min.* See HEAVY SPAR.

CEDREN, CEDROLE. The liquid and solid portions of oil of juniper (*Juniperus virginiana*), which are partially separated by straining.

Cedren. Obtained by distilling cedrole with anhydrous phosphoric acid, and then over potassium, until the latter ceases to be coated red; or by repeated distillation of the liquid oil strained from the crude oil; this cedren is not as pure as the former. Cedren is a slightly yellowish, peculiar aromatic liquid, of a feeble, then peppery taste; spec. grav. = 0.984 at 58°, boils at 478°, spec. grav. of vapor = 76.40 (by exper. = 7900). Formula, $C_{32}H_{24}$.

Cedrole. The solid remaining after pressure is perfectly purified by repeated crystallization from alcohol. Brilliant, white, silky needles, of a peculiar odor, fusible at 165°, congealing to a crystalline mass; boils at 540°, spec. grav. of vapor 8270 (by exper. 8400); slightly soluble in water, much more in alcohol. Formula, $C_{32}H_{26}O_2$, or it is hydrate of cedren, $C_{32}H_{24} + 2HO$. *Walter.*

CEDRINET. *Prep.* The rectified empyreumatic oil of tar of beech wood is freed from acetic acid by carbonate of potassa, treated with strong caustic potassa lye, the alkaline solution freed from the insoluble, (eupion, capnomore, &c.), the potassa saturated with acetic acid, which causes the separation of another portion of oil, it is then distilled, and when about $\frac{1}{3}$ has passed over, the rest is tried, whether a drop of the oil, distilling over, occasions a red precipitate with persulphate of iron. As soon as this takes place, the oil is collected separately. The red color with persulphate of iron and a subsequent precipitate of red crystalline needles is produced by all substances which easily part with oxygen, and even the air renders the liquid red.

Prop. Red needles, burning with flame, without leaving a residuum; sulphuric free from nitric acid, dissolves it with an indigo-blue color, and when heat is applied decomposes it,

CEMENT.

concentrated nitric acid decomposes it; insoluble in bisulphuret of carbon, water, alcohol, ether, oil of turpentine, oil of almonds, &c., dissolves in creosote, with a purple color.

CELESTINE. *Min. Syn.* Prismatoidal Hal-Baryte, *M.* Sulphate of strontian. *Descrip.* Cryst. Right Rhombic, the main vert. prism = 103° 58', parallel to which its cleavage is distinct, less so parallel to terminal plane P. It also occurs fibrous, columnar, and granular. *H.* = 3—3.5. *G.* = 3.92—3.963. Color white, often bluish or reddish; transparent, subtranslucent; lustre vitreous, sometimes inclining to pearly; streak white; fracture imperfectly conchoidal, uneven. Very brittle.

Behavior and Analysis. The crystals decrepitate, and fuse readily on charcoal in the outer flame to a white enamel, which has an alkaline reaction, and in the inner flame is reduced to a hepar. It usually communicates a purplish tint to flame, which is rendered more distinct by dissolving it in muriatic acid, evaporating to dryness, moistening it with alcohol, spreading it on paper, and inflaming it. It dissolves in borax with intumescence to a clear glass, becoming yellow or brown on cooling; soluble in mic. salt to a clear bead; with fluor spar it fuses to a clear glass, becoming a white enamel on cooling. It is decomposed by long boiling with a solution of strong or by ignition with dry carbonated alkali, forming carbonate of strontia, or is reduced by ignition with charcoal to sulphuret of strontium.

All analyses show that it is essentially a simple sulphate of strontia, containing often small quantities of sulphate of baryta and lime, oxide of iron, &c. Formula, SrO, SO_3 , which gives 56.36 per cent. strontia.

Local. In limestone or sandstone; in trap rocks and in beds of gypsum, in which it is often associated with sulphur, as in the fine specimens from Sicily; other localities are Bex, in Switzerland; fibrous C., of a blue color, in clay, at Dornberg, near Jena. It is also found at Aust Ferry, near Bristol; in trap rocks near Tamtallan, in East Lothian; near Knaresborough in Yorkshire; at Norton, in Hanover. In the United States on Strontian Island, Lake Erie, Schoharie, and Lockport, New York, Rossie, St. Lawrence county, N. York; fibrous, like the Jena variety, occurs in Huntingdon county, Pennsylvania.

CELLULAR TISSUE. Fibrous tissue, composed of a material which, by boiling with water, is wholly converted into GELATIN.

CEMENT. *Tech.* *Ger.* Kitt; *Fr.* Ciment, Cément, Lut. A paste of very different composition applied to unite solid surfaces, by hardening between them, and rarely forming a combination with the constituents of either surface. The most common of all cements are mortar and hydraulic cements. See MORTAR.

In many cements, pulverulent substances are mingled with a glutinous or very adhesive material, and do not combine chemically, in others a chemical combination ensues. Those designed to stop up crevices and joints in apparatus temporarily put together are termed lutes. The following are some of the numerous recipes for cements:

Lutes. 1. Gypsum cast between paper; it

may be mixed with water, or better with milk, glue-water, &c. 2. Dry slacked lime and strong glue-water mixed to a stiff paste; or the same with white of egg is well adapted for porcelain, &c.; it may also be made of lime and blood. This lute will not bear much moisture. 3. Cheese, boiled with a little water, and rubbed to a paste with slacked lime, hardens readily. 4. Clay, iron-filings, and gum mucilage becomes hard and adheres tenaciously. 5. Ground flax-seed made into a stiff paste with water, milk, glue-water, or lime-water closes perfectly, hardens soon, and resists acids, &c. 6. Boil linseed oil, fuse caoutchouc in it, add pipe-clay, and incorporate them thoroughly; more caoutchouc prevents too rapid hardening; it should be kept in a moist and cool place. It resists acids more or less, and not hardening during distillation, &c., the parts of the apparatus may be moved about without causing openings, or, if it does, the pressure of the finger closes them. 7. Fused caoutchouc alone resists acid vapors and the temperature of boiling sulphuric acid.

Resinous Cements. 1. Any varnish may answer the purpose where a thick layer is not required, for they are apt to shrink. 2. *Diamond cement.* Fish-glue is softened in a little water, dissolved in boiling brandy, and mixed with a very concentrated solution of mastic, gum ammonia, &c.; it should be kept in a corked vial, and warmed when used. It cements porcelain, glass, &c., powerfully, and resists moisture to some extent. Keller recommends the following mode of preparing it. 2 pts. fish-glue, cut into fine pieces, are left for 24 hours covered with 16 pts. water, then boiled down to 8 pts., mixed with 8 pts. alcohol, and strained through linen. This liquid is mixed while hot with a solution of 1 pt. mastic in 9 pts. alcohol, and to the whole $\frac{1}{2}$ pt. gum ammoniac, finely pulverized, added gradually, and the liquid rendered perfectly homogeneous. In using it, both cement and the fragments are made as warm as possible, both pieces allowed to dry, then again rubbed over with the cement, and pressed together. After 5 or 6 hours it is perfectly hard. It is not applicable to vessels of porous earthenware; the best cement in this case is a thick solution of shell-lac in spirits of wine. (*Polyt. Cent. Blatt.* 1843, in *Ch. Gaz.* i. 666.) 3. Rosin and wax melted together and mixed with fine brick-dust forms a good cement between brass and glass, as in many kinds of physical apparatus; it is applied melted; 3—5 rosin, 1 wax, and 1 brickdust (Spanish brown or ochre) are good proportions. Wax and terpentine form a good cement, which, for convenience, may be cast into sticks and melted off by a hot iron. White wax, white rosin, and a little Canada balsam form a good and nearly colorless cement. 4. *Cement for Glass and Porcelain.* M. Hänsle recommends a mixture of 2 pts. shell-lac and 1 pt. terpentine, which are fused together and formed into sticks. This may also be employed for cementing wood, &c., when dissolved in spirit and evaporated to the consistence of a syrup. Hensler grinds 3 pts. litharge, 2 pts. of recently burnt lime in powder, and 1 pt. white bole to a mass with linseed-oil varnish. This cement is very tenacious when allowed to dry sufficiently long. *Chem. Gaz.* iii. 27.

Fire cements. 1. For furnaces, crucibles, &c. Fire-clay and brickdust, or fire-clay and burned clay (broken crucibles) kneaded well together with water, and spread in layers on joints, and thoroughly air-dried, resists heat without cracking. It may also be employed for coating glass retorts, by spreading it as a stiff paste or thinning it with water and spreading with a brush. A little hair added to it, gives greater tenacity. 2. Clay and brickdust mixed with water and $\frac{1}{16}$ pt. borax gives a difficultly fusible cement; clay and red lead may be used. To make it less fusible, common clay and sand may be employed. 3. For iron vessels, &c., mix 50—8 pts. fine and pounded cast iron turnings with 2 pts. powdered sal-ammoniac and 1 pt. flowers of sulphur into a paste with water, and apply it immediately; it forms a chemical union, and hardens rapidly. According to some, the sulphur may be omitted. 4. Four pts. iron filings or turnings and 3 pts. of a mixture of common and burned clay are made into a paste with salt water. See also MASTIC and MORTAR.

CEMENTATION. *Tech.* Is generally applied to the conversion of iron into steel by imbedding the former in charcoal. The theory of the operation is, that the outer surface of iron takes up a large portion of carbon from the charcoal in contact with it, and transmits a portion of the carbon to the layer of metal next below the surface, and thus in succession to the centre, for the steeling is observed to progress from the outside of a bar to the centre. Cementation is also applied, but more rarely to the reduction of a metallic oxide imbedded in charcoal. In this case it may be partly reduced by the gradual progression of carbon from particle to particle as above, but it is more probable that the reduction is due to carbonic oxide, whether produced by the outside layer of oxide in contact with the charcoal, or by the carbonic oxide of the surrounding fire.

CENTAURIN. A dark brown bitter extract, from *Erythrae Centaureum*. The same name is also given to CNICIN.

CEPHALOTE. See BRAIN.

CERAIN. CERAIIC ACID. See WAX.

CERASIN. See GUM.

CERASITE. *Min.* See MENDIFFITE.

CEREBRIC ACID, CEREBROLE, CEREBROTE. See BRAIN.

CERIC ACID, CERIN. See WAX.

CERINE. *Min.* See ALLANITE and ORTHITE.

CERITE. *Min.* Rhombohedral Cerium-ore, *M.* Siliciferous Oxyd of Cerium, Silicate of Cerium, Ochroite, Cererite. *Descrip.* It occurs massive, with a granular structure. *H.* = 5.5. *G.* = 4.912. Color clove brown or rose-red, passing into gray; subtranslucent; lustre adamantine; streak grayish-white; fracture splintery; rather tough.

Behavior. Yields water in a closed tube, becomes brownish yellow on charcoal; slowly dissolved in the outer flame in borax, giving a dark yellow glass, which becomes nearly colorless on cooling, and may be white-enamelled by flaming; the inner flame shows a slight reaction of iron; it behaves similarly in mic. salt, leaving a skeleton of silica; soda fuses with it to a dark yellow cinder.

CERIUM.

The following analyses are, 1, by Vauquelin, 2 by Hisinger, but it must be remembered that the discovery of Lanthanum and Didymium by Mosander requires new investigations of all the cerium minerals.

	1.	2.
Protoxyd of cerium.....	67	68.59
Silica	17	18.00
Oxyd of iron.....	2	2.00
Lime.....	2	1.25
Water.....	12	9.60
	100	99.44

Local. Bastnaes, near Riddarhyttan, in Westmanland, forming a bed in gneiss, and associated with mica, hornblende, copper pyrites, cerine, &c. It bears considerable resemblance to the red granular variety of corundum, but is readily distinguished by its hardness.

CERIUM. The oxides were discovered contemporaneously in 1803 by Klaproth and Hisinger and Berzelius. The oxide supposed to be simple was found by Mosander in 1839 to contain another metal, Lanthanum, and still later a third metal Didymium. These 3 metals occur in Cerite, Allanite, Orthite, Gadolinite, Ytrocercite, Mosanderite, &c. The discovery of these three associated metals render all previous descriptions of the compounds of cerium imperfect; it is therefore advisable to omit these descriptions until more perfect modes of separation have been discovered. The following notices of the separation of all three together, and some of their characteristic properties, may be sufficient. 1. Dissolve finely-pulverized cerite in nitromuriatic acid, evaporate to dryness, gently ignite, dissolve in water, precipitate oxide of iron by benzoate of ammonia, then hydrated oxide of cerium, &c., by ammonia, dissolve the latter in muriatic acid, evaporate and ignite as long as chlorine passes off, and precipitate by potassa. 2. Dissolve an excess of heated cerite in ignited oil of vitriol, extract with cold water, put an excess of crystals of sulphate of potassa in the solution, filter, and wash the double sulphate of cerium, &c., and potassa. (*Beringer.*) The oxide of cerium thus obtained contains some 40 per cent. oxide of lanthanum, and a portion of oxide of didymium. Dissolve the oxides in nitric acid, evaporate to dryness, ignite to drive off the acid, digest for some hours at a gentle heat in very dilute nitric acid (1 acid to 50—100 water) which dissolves oxide of lanthanum. (*Mosander.*) To separate cerium and didymium, add a strong solution of valeric acid to a strong solution of their nitrates; valerate of didymium precipitates. *I. Bonaparte.*

Lanthanum forms 2 oxides, protoxide (or lanthana) and hyperoxyd. The hydrated protoxide is white, faintly blues litmus, forms colorless salts, with an astringent taste, precipitates with caustic or carbonated alkali. If it be brick-red after ignition, it indicates the presence of didymium. *Mosander.*

Cerium forms 3 oxides, white protoxide, white sesquioxide, and a yellowish cerosoceric oxide. The hydrated protoxide is white, forming colorless salts, which have a sweet, astringent taste, redden litmus, and are precipitable by caustic

CETRARIN.

alkali. The hydrated sesquioxide is sulphur-yellow, forms yellowish or reddish yellow salts, with a sweet and styptic taste, precipitable by alkalies. Its equiv. is greater than that of lanthanum. *Berzelius, Mosander.*

Oxide of didymium is brown, becoming dirty white by ignition. The sulphate is rose and amethyst-red colored. *Mosander.*

CERIUM OCHRE. *Min.* A yellow pulverulent, or scaly incrustation on the pink scapolite of Bolton, Massachusetts; dissolves in muriatic acid with a yellow color; dissolves in borax with an orange-red, transparent glass while hot, and pale green when cold; contains oxides of cerium, lanthanum, uranium, and yttria. *Jackson.*

CEROSIN, CEROXYLIN. See **WAX.**

CERULIN. See **INDIGO.**

CERUMEN. Ear-wax; *Ger.* Ohrenschmalz. It is an emulsic combination of soft fat (stearin and elain) and albumen, together with a peculiar substance, a yellow, bitter extractive, soluble in alcohol, an extractive soluble in water, and salts, probably lactates of lime and alkali; it contains no chlorides and no soluble phosphate. When the wax hardens, causing deafness, it may be softened by oil of terpentine or olive oil, which liquefies the fat. *Berzelius.*

CETEN, CETIN. See **CETYL.**

CETRARIN. *Chem.* The *Cetraria Islandica*, Iceland moss, yielded, in Berzelius's analysis, starchy matter (lichenin) 44.6, bitter principle (cetrarin) 3.0, uncrystallizable sugar 3.6, chlorophyll 1.6, extractive matter 7.0, gum 3.7, bifumarate of potassa and lime mixed with phosphate of lime 1.9, and amylaceous fibre 36.2 (= 101.6).

Lichenin. Found in this and other lichens, and called moss-starch. Let 1 pt. fine lichen macerate 24 hours in 18 pts. cold water, containing $\frac{1}{10}$ pt. pearlash, stirring it frequently; let the liquid drain on a cloth, and macerate it again with water, until the bitter principle and potassa are removed; boil the lichen in 9 pts. water, till reduced to $\frac{2}{3}$, filter while hot through a cloth, and subject the residue to pressure. On cooling, the liquid becomes a gray-colored opaque jelly, which contracts and separates from the water, and is dried on blotting paper. The black color is removed by dissolving in boiling water, which leaves, on cooling, a colorless, opaque jelly.

Prop. It has little taste; in thin plates is transparent; swells in cold water into a jelly; dissolves in boiling water into a mucilage; is colored blue by iodine only when concentrated; its aqueous solution exposed to the air becomes acid; subacetate of lead forms a precipitate, insoluble in water, soluble in acetic acid; digested with sulphuric acid at 151°, it yields starch sugar. Guerin-Vary's analysis leads to the formula, $C_{10}H_{11}O_{10}$, but it is more probable that it should be $C_{10}H_{10}O_{10}$.

Cetrarin. Boil the moss with alcohol as long as it has a bitter taste, distil off the greater part of the alcohol, express the impure cetrarin, which deposits in the residue, wash with a little water, then with ether or alcohol of 0.83, finally dissolve in boiling absolute alcohol; it separates on cooling.

Prop. A white, inodorous powder, with an

intensely bitter taste, when dissolved in alcohol; becomes brown at 257°, and decomposes wholly at 392°; scarcely soluble in hot or cold water, in essential oils, not at all in fixed oils, 100 pts. boiling absolute alcohol dissolve 1·7 pts., 100 pts. boiling ether 0·93; the solutions are neutral. Dry cetrarin is not altered by the halogens; it is decomposed by continued boiling with water: it is changed into a brown substance by sulphuric and phosphoric acids and excess of caustic alkali, into a brown resin, and oxalic acid by nitric acid, into a blue substance by warm concentrated chlorohydric acid. It combines with alkali and alkaline earth, precipitates the salts of iron dark red, of copper green, of lead and silver white, of other oxides with more or less color. Its composition is unknown. The cetrarin-blue obtained with muriatic acid is rapidly changed into ulmin by alkali, is dissolved by sulphuric acid with a blood-red, by nitric acid with a carmine, then a yellow color.

Herberger.

CETYL. Aethalyl. A hypothetic radical in spermaceti and substances obtained from it. Spermaceti consists mainly of *cetin*. By the action of potassa on sperm the hydrated oxide of cetyl, *ethal*, *cetylic acid*, and *ceten* are obtained. By the action of chloride of phosphorus, of sulphuric acid, and phosphoric acids on ethal we obtain *chloride of cetyl*, *sulphate of cetyl* and *potassa*, and *ceten*. Formula of cetyl, $C_{32}H_{33}$. Sym. Cet.

Cetin. *Prep.* Spermaceti is digested in an equal quantity of cold alcohol of 0·816, left for 24 hours at 68°, and filtered; the undissolved residue is treated with boiling alcohol in successive portions till the alcohol, when evaporated, ceases to exhibit traces of oil.

Prop. On cooling from fusion or solution, it crystallizes in white brilliant plates or pearly scales; inodorous and tasteless; it fuses at 120°; at 680° volatilizes without decomposition; is insoluble in water, 100 pts. boiling alcohol of 0·821 dissolve 2·5 pts. of cetin, the greatest part of which is deposited as the solution cools; soluble in ether, wood-spirit, essential and fixed oils; subjected to dry distillation it gives off water, carbonic acid, and oxide, olefiant gas at 90 per cent. of a mixture of cetin, cetylic acid, and ceten, and no ethal. It consists of $C_{64}H_{64}O_4$, or the elements of 1 eq. cetylic acid, $C_{32}H_{31}O_3 + 1$ eq. oxide of cetyl, $C_{32}H_{33}O = C_{64}H_{64}O_4$, and it is probable that these arise from decomposition by potassa. By the action of powdered potassa on sperm at 212° to 230°, the only products are cetylic acid and ceten. By oxidation with nitric acid, adipic acid, among others, is produced, but no suberic acid, and by distillation no sebatic acid; hence sperm contains neither margaric nor oleic acid, as Dumas and Peligot assumed. *J. L. Smith.*

ETHAL. Syn. Hydrated oxide of cetyl. It was first obtained by Chevreul by the action of potassa on sperm, and termed Aethal (Aether alcohol) from its analogy to the alcohol series; this view was confirmed by Dumas and Peligot.

Prep. Coarsely powdered potassa is added to fused sperm with constant stirring, and when the mass is fully solid, it is first treated with water, then with muriatic acid, and the oily stratum floating on the liquid is again treated

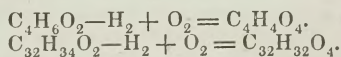
with potassa, water, and boiling acid. The mixture of ethal and cetylic acid is digested with milk of lime, and ethal separated from the cetylate of lime by cold alcohol.

Prop. A colorless solid, melting at 118°; when slowly cooled crystallizing in brilliant plates, has neither odor nor taste; may be easily volatilized alone or with water. Alcohol of the spec. grav. 0·812 dissolves it in any proportion when fused, but it is partly deposited as the solution cools; the solution has a neutral re-action; insoluble in water; when heated in the air it burns like wax; nitric acid decomposes it; sulphuric acid combines with it by a gentle heat; by a stronger decomposes it. Form. $C_{32}H_{34}O_2 = C_{32}H_{33}O + HO$, or $CetO, HO$.

Sulphocetylic acid. Aethalschwefelsäure, *Berz.* Bisulphate of oxide of cetyl. Formed by digesting in a water-bath, ethal, and oil of vitriol. If this compound be dissolved in alcohol, and tincture of potassa be added, sulphate of potassa separates, and ethal and the sulphocetylate of potassa remain in solution; after evaporation the crystals are recrystallized, and washed with ether, which leaves the salt in white pearly scales. Formula of the salt, $C_{32}H_{33}O, KO + 2SO_3$.

Protochloride of Cetyl. Aethylchlorür, *Berz.* Formed by distilling equal volumes of ethal and chloride of phosphorus, PCl_5 , when chlorohydric acid, chlorides of phosphorus, and, lastly, cetylous chloride pass over, and phosphoric acid and phosphate of cetyl remain. The cetylous chloride is washed with cold, then with boiling water, and to remove all ethal may be retreated with chloride of phosphorus. Form. $C_{32}H_{33}Cl = Cet, Cl$.

Cetylic acid. Ethalic acid. Formed from sperm with ethal by means of potassa, or with ceten by dry distillation. It is combined with lime or baryta, the ethal extracted by alcohol, the cetylic salt decomposed by muriatic acid, and the cetylic acid purified by solution in ether. It is a colorless, inodorous solid, crystallizing on cooling from fusion at 131°, distilling unchanged, insoluble in water, readily in alcohol and ether. Form. $C_{32}H_{31}O_3 + HO$. It is formed from sperm by contact of potassa, which separates the sperm into cetylic acid and oxide of cetyl, the latter of which assumes the water of the potassa, and is converted into ethal. Thus, $C_{61}H_{61}O_4 + KO, HO = KO, C_{32}H_{31}O_3 + HO, C_{32}H_{33}O$. From this view of the decomposition there is no necessary analogy between its formation and that of acetic acid from alcohol, although both alcohol and ethal compared with their respective acids, each lose 2 eq. hydrogen and assume 2 eq. oxygen, as thus shown:



The beginning and end are the same, but the nature of the change is different. To render the changes analogous, aldehyde should separate by potassa into acetate of potassa and alcohol.

Cetylate of potassa is white, pearly, insoluble in ether, decomposed by much water; the soda salt forms large, pearly laminae.

Ceten. Aethalol, *Berz.* Formed, together with

hydrous cetylic acid, by the dry distillation of sperm, or by repeatedly distilling ethal with dry phosphoric acid, which abstracts 2 eq. water. It is a colorless oily liquid, insoluble in water, soluble in alcohol and ether; burning with a smoky flame, boiling at 527°; spec. grav. of vapor = 8007 (4 vols.); by calcul. = 7843. Those who assume the analogy of ethal and alcohol apply the same to ceten and olefant gas.

CEVADIC ACID. See VERATRIN.

CEYLONITE. *Min.* See SPINEL.

CHABAZITE. *Min. Syn.* Rhombhedral Macrotypos, and Hexagonal Kouphone-Spar, *M.* Rhombohedral Zeolite, Levyne, Mesolin, Gmelinite, Sarcosite, Hydrolite, Acadiolite. *Descrip.* Cryst. Hexagonal, combining both homoedric and hemiedric forms; the rhomb. = 94° 46', in the planes of which it cleaves. *H.* = 4—4.5. *G.* = 2.08—2.17 (*Chab.*), 2.06

(*Gmel.*), 2.16 (*Levyne*). Color white, reddish; lustre vitreous; transparent, translucent; brittle with uneven fracture.

Behavior. Similar to the zeolites giving off water, swelling, fusing to a slightly vesicular, subtranslucent enamel; decomposed perfectly by chlorohydric acid, Chabazite, Levyne, and Mesolin leaving a gelatinous powder, Gmelinite, Sarcosite, and Hydrolite forming a perfect jelly.

Analysis. 1. *Chabazite*, from Nova Scotia; 2, from Fassathal, both by Hoffman; 3, from Gustassberg, by Berzelius; 4, from Aussig, by Rammelsberg; 5, from Renfrewshire, by Connel; 6, *Levyne*, from the Faroe Isles, by Berzelius; 7, by Arfvedson; 8, *Mesolin*, by Berzelius; 9, *Sarcosite*, from Castel, in the Vincentine, by Vauquelin; 10, *Gmelinite*, from Glenarm, in Antrim country, Ireland, by Connel; and, 11, by Rammelsberg.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Silica.....	51.46	48.63	50.65	48.363	50.14	48.00	48.38	47.50	50.00	48.56	46.40
Alumina.....	17.65	19.52	17.90	18.615	17.48	20.00	19.28	21.40	20.00	18.05	21.08
Lime.....	8.91	10.22	9.37	9.731	8.47	8.35	8.70	7.90	4.25	5.13	3.67
Soda.....	1.09	0.56	—	0.255	—	2.86	—	4.80	4.25	3.85	7.30
Potassa.....	0.17	0.28	1.70	2.565	2.58	0.41	2.50	—	—	0.39	1.60
Water.....	19.66	20.70	19.90	(20.471)	20.83	19.30	21.14	18.19	20.00	21.66	20.41
	98.94	99.91	99.52	100	99.50	98.92	100	99.79	98.50	98.64	100.46

Nos. 1 and 10 contained, in addition, small amounts of oxide of iron, and 6 a little magnesia.

From these analyses it is clear that the different minerals named are one and the same, the main difference lying in the relative proportion of the two alkaline bases, and, according to the predominance of either, the species may be divided into two varieties, from 1 to 8 being Lime-chabazite, 9 to 11 Soda-chabazite. The general form, probably is $3\text{CaO}, 2\text{SiO}_3 + 3(\text{Al}_2\text{O}_3, 2\text{SiO}_3) + 18\text{HO}$, or a double $\frac{2}{3}$ silicate of alumina and alkali, with water, in which the alkali is principally lime or soda.

Local. It usually occurs in trapean rocks, basalt, syenite, &c., associated with analcime, heulandite, and other zeolitic minerals. The principal localities are Greenland, Iceland, Nova Scotia, the Faroe Isles, Giant's Causeway, Renfrewshire, Isle of Skye, Aussig in Bohemia, Fassathal, Sweden, &c. Levyne occurs at Glenarm, county Antrim; Skagastrand, Iceland; Dalsnypen, Faroe; Disco Island, Greenland; in the Vincentine, &c. Gmelinite (Sarcosite) occurs in the Vincentine, Glenarm, Sandwich Isles. In the United States, at Stonington and Hadlyme, Connecticut; Charleston and Chester, Massachusetts; Piermont, New York; in the railroad cut through the trap of Bergen Hill opposite New York city.

CHALCOLITE. *Min.* See URANITE.

CHALILITE. *Min.* See THOMSONITE.

CHALK. *Min. Ger.* Kreide; *Fr.* Craie. See CALCAREOUS SPAR. *Geol.* The cretaceous group, including the chalk and green-sand formations, is extensively developed in England and the western parts of Europe, and extends through Germany into Russia. The group in the United States consists mainly of green-sand and its associates, but little true chalk having been

found; there is, however, a small admixture of cretaceous particles in the green-sand of Delaware. (*J. C. B.*) The chalk formation contains flint-nodules disseminated through it, generally in regular strata. According to Ehrenberg, "Many and probably all white chalk-rocks are the produce of microscopic coral-animalcules, which are generally visible to the naked eye, possessing calcareous shells of $\frac{1}{24}$ to $\frac{1}{288}$ line in magnitude, and of which much more than a million are well preserved in each cubic inch, i. e. much more than ten millions in a pound of chalk." *Tech.* Chalk is employed for marking from its whiteness, fineness, and the ease with which it is abraded. It is farther employed by burning to lime, in agriculture, for mortar, for neutralizing acids, &c. It is sometimes fined by washing over, in making *Whiting*, *Spanish white*, *Crayons*; *Ger.* Schlemmkreide; *Fr.* Blanc de Troyes ou de Meudon.

Black chalk is another name for a soft black slate. *Red chalk* is sometimes applied to Bole.

Chalk stones, see under CONCRETIONS.

CHALYBEATE. See MINERAL WATERS.

CHAMELEON MINERAL. See Manganate of Potassa under MANGANESE.

CHAMOISITE. *Min.* Sideroshisolite. It occurs in minute crystals, with a cleavage *H.* = 2—3. *G.* = 3—3.4. Color velvet-black or dark-greenish gray, with a splendid lustre; opaque; streak leek-green, greenish gray.

Behavior. Heated, it at first becomes black and magnetic; afterwards it changes to an ochre-red; in a glass tube, water is evolved; it forms a jelly with muriatic acid; the massive variety, chamoisite, effervesces with acids, on account of the carbonate of lime with which it is mixed. The solution obtained with the crystalline variety, sideroshisolite, is greenish yellow.

CHAMOMILE.

CHARCOAL.

Analysis. 1. Sideroshisolite by Wernekink;
2, Chamoisite by Berthier:

	1.	2.
Silica.....	16.3	12.0
Protoxyd of iron	75.5	50.5
Alumina.....	4.1	6.6
Water.....	7.3	14.7
Carbonate of lime.....	—	14.4
Carbonate of magnesia... —	—	1.2
	103.2	99.4

It is difficult to establish a probable formula from the analysis.

Local. Crystallized specimens occur in cavities of magnetic pyrites and sparry iron-ore in small crystals, at Conghonas do Campo, in Brazil. Chamoisite occurs in beds of small extent, in a limestone mountain, abounding in ammonites, at Chamoisin, in the Valais. *Dana.*

CHAMOMILE. The *Anthemis nobilis* (common chamomile, *Ger. Römische Kamille*) were analyzed by Wyss, but one of the most important principles, the volatile oil, was not determined. Freudenthal's analysis of the dried flowers of *Matricaria Chamomilla* gave volatile oil 0.28, resin 7.89, bitter extractive 8.57, gum 7.39, bitartrate of potassa 5.31, phosphate of lime 0.97, woody fibre, soluble albumen, water, and loss 69.6. The bitter principle is soluble in water and alcohol.

Oil of chamomile is chiefly obtained from the *Matricaria*, although similar oils appear to be yielded by the *Anthemis*, *Arnica montana*, and *Achillea millefolium*. It is blue at first, becoming brownish, has the odor of chamomile. Bornträger's late results with the oil are the following. It retains its blue color by rectification with water; by shaking with ether, the latter leaves by evaporation a colorless oil, of a different odor from the blue; the blue oil is soluble in alcohol and ether with a blue color; cooled below 32° it becomes thick, but deposits no stearopten, although leaves of a colorless stearopten are often seen in the commercial oil, when it has become very thick; by distillation, there remains in the retort a brown resinous mass. From the numbers of the last analysis its formula is about $C_{10}H_8O$.

CHAMPAGNE. *Tech.* A wine characterized by its effervescence when uncorked; prepared chiefly in France, by a long-continued, slow, or successive fermentations. Wines containing much sugar and little tartaric acid are adapted to champagne, but any kind may be converted artificially into a kind of champagne by sweetening it, and compressing carbonic acid in it, as is actually done on a large scale in France, Germany, &c.

CHARCOAL. *Tech. Ger. Kohle; Fr. Charbon.* The residue after exposing organic matter to heat apart from the air; it is therefore a porous mass, consisting of fixed carbon, the inorganic substances, and a trace of volatile matter. From their origin and uses, two kinds may be distinguished, *animal* and *vegetable*; for the former, see **BONE-BLACK**. The latter, or *common charcoal*, is obtained by charring the trunks and stouter branches of trees, the object

being charcoal alone, or charcoal and the volatile matters. In the latter case the wood is enclosed in iron cylinders, or retorts, (see **AMMONIUM** and **GAS**.) which are heated externally, and the gaseous products passed through cooled tubes, where the liquid products condense. See **dry distillation of Wood**.

In the manufacture of charcoal for gun powder, moderately thick branches of willow are charred in a similar manner, although the volatile products are of no account, since the temperature, which is very important, may be regulated at pleasure. For in the ordinary methods of charring under movable covers, the temperature is so high as to cause the inorganic constituents to sinter together, producing a glazed and stoney surface. By a slow and careful ignition in cylinders a softer coal is obtained.

Charcoal is usually made by piling wood, covering it over with a compact earthy layer, and firing it, when the slow combustion of a portion of the volatile combustibles and of the wood itself expels the residue of the volatile matter. Such heaps are termed *charcoal pits*. The following is an outline of the process. Logs not more than 6 ft. long and 6 inches thick are laid either horizontally or vertically (*Ger. Liegende oder Stehende Meiler*), and stems and branches are employed to fill up the interstices. The whole is covered with from 3 to 5 inches of earth, or still better with a mixture of earth and fine charcoal over a layer of leaves and small brush-wood, and kept moistened with water. The heap is ignited by coals thrown into the chimney, when the fire "draws to the sides" towards small openings left around the base. A heavy, yellowish-gray smoke and much watery vapor first appears, which condenses on the outer covering, called *sweating*. The fire should be rapid during sweating, to avoid explosions, and the heap carefully sweated off, requiring 16 hours from the beginning. The general shrinkage of the wood opens cracks, when the coalman mounts the heap, rams the wood together, and replaces the covering. When the heap is fairly warmed, and no farther explosions to be feared, the openings are closed, and the heap suffered to burn several days, (3—4,) while the collier only watches to secure uniform combustion in all parts. A few openings are now and then made for the escape of the tarry matter, &c., and a few others at the foot; and after 4—8 days others halfway up the heap to char the outside logs. If a blue flame rises, the openings are stopped, and made lower down. When the fire gradually breaks out uniformly around the base, the charring is complete. The heap has become smaller and very irregular in form from shrinking, &c. The whole time required is from 6 days to 4 weeks, according to the size. A heap of 3000 cub. ft. requires about 15 days.

Economy is an important point in charring, for the object is to employ as little of the charcoal as possible for expelling the volatile matter, and no doubt the combustion of some of the volatile matter assists in it. There is a great difference in the amount obtained by slow and by rapid charring, as shown by the follow-

CHEESE.

ing table of results obtained by Karsten, with wood thoroughly air-dried:

	Rapid charring.		Slow charring.	
	Charcoal	Ash.	Charcoal	Ash.
Young oak...	16.39	0.15	25.45	0.15
Old oak....	15.80	0.11	25.60	0.11
Young beech	14.50	0.375	25.50	0.375
Old beech...	13.75	0.4	25.75	0.4
Old birch ...	11.90	0.30	24.40	0.30
Old savin ...	13.90	0.15	24.85	0.15
Young fir ...	16.00	0.225	27.50	0.225
Young pine..	15.40	0.12	25.95	0.12
Rye straw...	13.10	0.30	24.30	0.30

Now, the composition of wood dried in the air shows 38½ per cent. carbon, or with 1 per cent. ashes, 39½, but by the best methods we get 28 to 30 of charcoal, and by the common methods 16 per cent. average. See table of Composition of Wood. To insure slow charring, little space should be left in the pile, and M. Bull recommends filling the interstices with fine coal, or *culm*, of a previous burning. This was tried in New Jersey, and found to give 10 per cent. more in bulk, and the charcoal was 20 per cent. heavier, and well charred. Experiments made in Saxony seem to confirm his conclusions. It may be farther observed that dry wood is decidedly superior to wet.

The ashes of charcoal is less in quantity than that of the wood from which it is produced, a portion passing off even by a very slow distillation, as in the gunpowder manufacture. The alkaline matter especially diminishes, being probably carried over in combination with acetic acid. *Dupont*.

Use. Charcoal is chiefly employed as a fuel, igniting readily, burning freely, with a strong heat, making a *clean fire*, from the absence of volatile and other matters. It is farther used in the manufacture of gunpowder and fireworks; as a decolorizer, disinfectant, and antiseptic. See ABSORPTION. It has been lately employed as a manure with beneficial results. See Johnson's Farmer's Encyclopedia and AGRICULTURE in the present work. From its imperfect conduction of heat, it is often used as a casing for heated pipes; and from the same property and its reducing quality it is useful in BLOWPIPE experiments. It is an important reducing agent employed in the arts, and in this respect is decidedly superior to any other, where the quality of the metal, &c., is important.

CHEESE. *Tech. Ger.* Käse; *Fr.* Fromage. This well-known produce of the dairy is made from skimmed, unskimmed milk, or cream, and is the product of a gradual change of the insoluble substances in milk. The milk is curdled by rennet, and as soon as the curd is firm enough, it is carefully stirred or shaken, to separate it more perfectly from the whey; it is then strained through a cloth, the curd upon the cloth being broken and cut up in order to drain off more of the whey. The good quality of the cheese is in proportion to its complete separation; and hence the practice in some places of heating it in contact with whey, as also the use of salt, which does not moisten

CHELIDONIN.

fresh cheese, but attracts the water present. It is then subjected to the increasing pressure of a screw-press, until sufficiently drained, when it may be salted, and exposed in the cheese-room to drying, where it undergoes a change, gradually assuming its peculiar flavor.

The quality of cheese depends upon the methods of making, the season, the nature of the soil, and its herbage, &c., for the odor of some plants (garlic) may be observed in it, but the mode of manufacture is the principal source of difference.

Cream-cheese is usually made from cream, or a mixture of it with milk. For the former, the cream, slightly soured, is exposed in moderately thin layers to the air, which dries it more or less in a few days, forming a tough coating on the surface.

The changes which cheese undergoes without putrefaction have not been studied, and those of a more or less putrescent nature are scarcely understood. See *Aposepidin* under CASEIN.

CHELIDONIN. The *Chelidonium majus* contains, according to Probst, among other substances, Chelidonic acid, Chelerythrin, Chelidonin, and Chelidoxanthin.

Chelidonic acid. Contained in the plant and root of the above, especially in the plant, and at all seasons. Extract the plant with warm water containing soda, supersaturate the clear filtrate with nitric acid, and precipitate with nitrate of lead; wash with water acidulated with nitric acid, decompose by sulphuret of sodium, and boil all together with bone-black; decompose the excess of sulphuret of sodium by acid, filter and concentrate the neutral solution, and precipitate the chelidonic acid in the cold by dilute sulphuric acid; by recrystallization from a hot aqueous solution, or retreatment with nitric acid and lead, it is obtained pure. *Prop.* Fine, colorless, inodorous crystals, of a strong acid taste, not volatile, soluble in 166 pts. water at 46°, and in 26 boiling, in 709 pts. alcohol (of 75 per cent.) at 72°; precipitates lime-water in excess, lead, mercury, and silver salts white; the lead salt separates if the solution be acidulated with nitric acid in silky needles, insoluble in dilute, soluble, strong, and warm nitric acid; the latter reaction is characteristic. The salts of the alkalies and magnesia are white, soluble, crystallizable, the soda salt very efflorescent; the salts of baryta, strontia, lime, and zinc are white, crystalline, less soluble in cold, more soluble in hot water; the salt of copper grass-green, crystalline, difficultly soluble; that of silver caseous, containing 56.5 per cent. oxide of silver, making the equiv. of the acid 89.5. Probst's analysis leads to the formula, $C_6H_5O_7$, the equiv. of which is 87. Probst's calculation for the equiv. from the silver-salt (83.119) is erroneous, as well as Liebig's formula, $C_7H_2O_6$. Probst in *An. der Ch. u. Ph.* xxix. 130.

Chelerythrin. Discovered by Probst and Polex at the same time; exists in all parts of the *Chelidonium majus*, especially in the root and unripe fruit; also in the root of *Glaucium luteum*. After extracting chelidonic acid, as above, the residue is extracted by sulphuric acid water, precipitated by ammonia, the precipitate drained by

pressure, dissolved in sulphuric acidulated alcohol, the alcohol distilled off, the aqueous solution precipitated with ammonia, the precipitate washed, dried by a gentle warmth, and extracted with ether, which mainly leaves chelidonin. The ethereal solution is evaporated, the residue dissolved in a very little dilute muriatic acid, which leaves a resin, the solution evaporated to dryness and extracted by ether, which leaves muriate of chelerythrin. By repeated solution of the latter in a little water, and evaporation to dryness, it is obtained pure, some muriate of chelidonin remaining each time; from its solution in absolute alcohol, it is obtained crystalline. *Prop.* Precipitated by alkali, it is grayish white, caseous, from an ether-solution terebinthic, from alcohol crystalline; is insoluble in water, the tincture is yellowish, with an acrid, burning taste; heated to 149° it becomes resinous; its solution in acids is brilliant orange-red, a characteristic color; the salts are generally soluble in water, with a similar but stronger taste than the base itself, an acrid narcotic action, and are precipitable by alkali and tincture of galls. The sulphate crystallizes with difficulty, is soluble in water and spirits of wine, little in absolute alcohol, not in ether, permanent in air, fusible; the phosphate crystallizes more readily, has the same solubility; the muriate is crystallizable from alcohol, with similar solubility; the acetate may be evaporated to dryness without losing acid; the chelidonate is soluble in water and alcohol. *Probst.*

Chelidonin. Found by Godefroy, then by Probst, Pollex, and Reuling; exists in all parts of chelidonium, most in the root. The ammoniacal precipitate in preparing chelerythrin, after treatment with ether, is dissolved in sulphuric acid water mixed with twice as much muriatic acid, the crystalline precipitate, settling after some time, is washed with cold water, treated with ammonia to remove all acid, re-dissolved in dilute sulphuric, precipitated by strong muriatic acid, digested with ammonia, dissolved in sulphuric, precipitated by ammonia, and dissolved in alcohol, from which it crystallizes in plates. *Prop.* Colorless, inodorous, of bitter taste, insoluble in water, soluble in alcohol and ether; loses 4.8 per cent. or 2 eq. water at 212° ; fuses at 266° to an oily liquid, burns with a luminous, smoky flame, without residue. Its salts are colorless, mostly soluble in water, with an acid reaction, those with a feeble volatile acid lose it by evaporation. The sulphate crystallizes, is soluble in water and alcohol, fuses at 122° to 140° ; the phosphate crystallizes more readily, has similar solubility, and is fusible; the nitrate forms beautiful crystals, of difficult solubility; the muriate is crystalline, dissolves in 325 pts. water at 64° , forms a double salt with chloride of platinum, which may be boiled with nitric acid without decomposition. Chelidonin is not poisonous. (*Probst.*) Form. $C_{40}H_{26}N_3O_6$. *Will.*

Chelidoxanthin. Found by Probst in the root, plant, and flowers of the chelidonium. After extracting the preceding substances, the residue, or the fresh-pressed root, after one extraction by alcohol, is extracted repeatedly by hot water, precipitated by subacetate of lead in

excess, the precipitate decomposed by sulphuretted hydrogen, the sulphuret washed with cold water until it appears yellow, when it is boiled with water as long as it imparts a yellow color; the yellow liquids are evaporated to dryness, digested successively with ammonia, ether, and absolute alcohol; the last solutions in absolute alcohol are evaporated, treated with dilute sulphuric acid, ammonia, and, lastly, with ether, which leaves chelidoxanthin as a yellow mass, that may be crystallized from solution in hot water. *Prop.* Yellow needles, difficultly soluble in cold, more so in hot water, and in dilute alcohol, not in ether; the solutions are yellow, with an intensely bitter taste, unaltered by alkali and acid, precipitable by tincture of galls. It appears to be the most active ingredient in *Chelidonium majus*. (*Probst.*)

CHEMISTRY. *Gr.* χημία; *Lat.* Chemia, Chymia; *Engl.* Chymistry; *Fr.* Chimie, Chymie; *Ger.* Chemie, formerly Scheidekunst; *Swed.* Kemi. The origin of the science, as well as its name, is involved in some obscurity. Geber, in the 9th century, issued the first treatise that we are acquainted with on chemistry or alchymistry, which signified the same. Julius Firmicus Maternus, a Roman writer under Constantine the Great, uses the expression, *Scientia chimia*; and we know that the Emperor Diocletian, in the 3d century, committed to the flames Egyptian works, πρὸς χημίας χημικοὺς καὶ ἀρχηγοὺς. Humboldt's opinion was that the name is derived from the word for Egypt, *chmi* or *Kemi*, as it is termed in the Hieroglyphics, the land of Ham. The word *chmi* signifies black, and in modern Coptic *cham* means the same. Whether derived from the black soil or not is uncertain. Hence the peculiar science received the name of the science of *chmi*, or of Egypt, or of the black land, where we may therefore infer it had its birth. It is not impossible that the term "The Black Art," may be traced to the same source.

From the scattered and often confused notices by ancient authors of the arts and sciences of ancient Egypt, but more especially from the discoveries in that country during the present century, it is certain that the most important branches of the chemical arts had their origin and were successfully practised in Egypt, prior to the prosperous periods of Rome or Greece. The reduction and refining of the precious metals, as well as of lead, copper, iron, &c., together with the use of fluxes; the manufacture of glass, plain and colored, of coarse and fine pottery; the art of dyeing and the highly refined art of calico-printing; and many others, which contain nearly all the principles of the modern chemical arts, (until the commencement of the present century,) were practised in Egypt some 2500 to 3000 years since, and some of them, if not all, probably 3500 or 4000 years since. We still employ terms derived from the Egyptians, besides the name of the science, Chemistry. Thus ammonia, from sal-ammoniac, is due the great temple of Jupiter Ammon, or Amon-Ra, near which it was and is still manufactured (see Sal-ammoniac under AMMONIUM). The term chemia was more especially applied to the refining, &c., of the precious metals, and hence the Latin term for gold,

CHENOCOPROLITE.

aurum, may be traced to the Egyptian *Aur* or *Our*, signifying the sun and gold.

It is extremely difficult to give a definition of the science of chemistry intelligible to the uninitiated, for to call it "the doctrine of the phenomena developed by chemical attraction or affinity" requires an exposition of the nature of Affinity. Nor is it easy to draw an exact line of demarcation between Physics and Chemistry, for the one calls repeatedly for the assistance of the other in order to develop and illustrate its laws. Physics investigates the *general* laws of matter, without reference to the peculiar kind of matter. The general laws of the equilibrium of forces in solids, liquids, and gases, elasticity, cohesion, gravitation, electricity, light, heat, sound, &c., belong exclusively to physics, and require no aid from chemistry; but the laws of electricity, light, sound, cohesion, &c., as modified by the peculiar nature of the substance in which they are studied, draw assistance from the chemist. In like manner, the laws governing the intimate union of unlike matter to a new and homogeneous substance, or the separation of a compound into heterogeneous elements or other compounds, is exclusively the province of chemistry.

As the science stands at present, it mainly consists of the preparation, composition, and properties of bodies, the greater part of the last of which are physical. A few excellent generalizations have been made, in regard to the laws of combination, but the science must be regarded as still in its infancy, and a vast field for exploration invites the inquiring mind, combined with an active hand. It is customary to divide the science into Inorganic and Organic, and to subdivide the latter into Vegetable and Animal Chemistry; but the line of demarcation between these ceases to be well-marked, the moment we are able to produce a true vegetable or animal substance from its ultimate elements. This having been already accomplished, we must regard the above divisions as those of a temporary convenience. In the same way special parts of the science have been separately treated, such as *Applied Chemistry*, which exhibits the application of chemical principles to the processes of the chemical arts; *Analytical Chemistry*, which teaches the methods of detecting the presence of the various elements in a compound, and the modes of ascertaining their relative quantities.

CHENOCOPROLITE. *Min.* *Ger.* Gänseköthigerz. *H.* = 2—3. It is mammillary, with a yellow or pale-green color; translucent; lustre resinous, shining; streak white; fracture conchoidal. Before the blowpipe, it evolves copious arsenical fumes, and fuses into a blackish scoria; when the heat is continued on charcoal, it fuses and yields a button of silver, but the slag contains metallic iron, which strongly affects the magnet. Chenocprolite appears, therefore, to be an arseniate of silver and iron. The principal localities of this species are at Clausthal, in the Harz, also in Cornwall, and at Allemont in Dauphny. *Allan.*

CHIASTOLITE. *Min.* See **ANDALUSITE.**

CHICA-RED. A red coloring matter which precipitates from a boiling infusion of the *Bigonia Chica*. It is vermilion-red, insoluble in

CHLORACETIC ACID.

cold water, soluble in alcohol, ether, fat oils, and alkalies, precipitable from the last by acids.

CHILDRENITE. *Min.* Cryst. Rhombic. *H.* = 4·5—5. Color yellow, and yellowish brown; lustre vitreous, inclining to resinous; translucent; streak white; fracture uneven. An incomplete analysis by Wollaston gave phosphoric acid, alumina, and iron. It occurs in minute crystals and crystalline coats, on sparry iron or quartz, near Lavistock, in Derbyshire.

CHILTONITE. *Min.* See **PREHNITE.**

CHININ and CHINOLEIN. See **QUININ.**

CHINOIDIN, CINCHOTANNIC ACID, CINCHONA-RED, CINCHONA-BITTER. See **CINCHONA.**

CHINOYL, CHINONE. See **QUINIC ACID.**

CHINOVIC ACID. See **QUINOVIC ACID.**

CHIOCOCCIN. A bitter, amorphous, alkaloidal principle obtained by Brandes from the *Chiococca racemosa*. According to v. Santen, it is identical with Emetin.

CHITIN. According to Odier, the basis of the horny parts of insects, wings, hair, &c., but it has not been minutely studied.

CHLOR, CHLORO. A prefix to many compound bodies, especially organic, containing chlorine, which may generally be found in the present work, by referring to part of the word following chlor, thus chlorbenzid is described under *Benzyl*. The following might not be so readily found; Chloranil, Chlorindin, Chlorisatin under *Indigo*, Chlorarsin under *Kakodyl*, Chloranthracenuse under *Naphthalin*, &c.

CHLORACETIC ACID. *Syn.* Chloracetylic acid, *Dumas.* *Prep.* Pure hydrated acetic acid, 1 drachm, is exposed in a jar of 1 gall. of chlorine to the sun's rays; after 24 hours the crystals on the sides of the vessel are dissolved out by a small quantity of water, which dissolves chloracetic, hydrochloric, oxalic, and acetic acids. The solution is evaporated in vacuo, over oil of vitriol and fused potassa; oxalic acid first crystallizes, then chloracetic acid. The mother-liquid is distilled with anhydrous phosphoric acid, which retains the water, and decomposes the oxalic acid, acetic acid first passing over, then chloracetic acid in crystals, which are freed from the acetic by wrapping them in paper, and leaving them in vacuo for 24 hours.

Prop. Colorless rhomboidal needles and plates, with a faint odor and caustic taste, very deliquescent in moist air, bleaches and corrodes the skin, has a very irritating and suffocating odor when heated, reddens vegetable blues without bleaching them; fuses at 115°, becoming solid at 108°, the spec. grav. of the liquid acid at 115° = 1·617; when heated with an excess of potassa, it is resolved into perchloride of formyl and carbonated alkali, or chloride of potassium, formiate and carbonate of potassa. Formula, $C_4Cl_3O_3 + HO$.

Salts. It combines with bases, its water being replaced by an equivalent of the base; and forming soluble salts, which possess a remarkable analogy with the acetates, and are decomposed with greater facility than the acetates by excess of alkali. *Chloracetate of Ammonia* is crystallizable; formula, $C_4Cl_3O_3 + NH_4O + 4 HO$.

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C. of Oxide of Ethyl. Prepared by distilling a chloracetate, or chloracetic acid, with sulphuric acid and alcohol, and adding water to the product, which separates the chloracetic ether as a colorless heavy oil, with an odor similar to heavy muriatic ether. Formula, $C_4Cl_3O_3$, AeO. *C. of Potassa.* Obtained by neutralizing the acid with carbonate of potassa, and spontaneous evaporation of the solution, in fine silky crystals, permanent in dry, deliquescent in moist air. Form. $C_4Cl_3O_3$, KO + HO. *C. of Silver.* Prepared by dissolving oxide of silver in the acid, and evaporation in vacuo, forms shining scales or grains, sparingly soluble in water, explodes when heated. Formula, $C_4Cl_3O_3$, AgO. *Liebig.*

CHLORAL. *Prep.* Dry chlorine is passed through anhydrous alcohol in a retort, at first in the cold, but afterwards a gentle heat is used to promote the action, for which a very long time is requisite to complete the decomposition. A very large quantity of chlorohydric acid is disengaged, and as soon as the chlorine, even at boiling, passes through unchanged, the operation is complete; the liquid generally solidifies on cooling, forming a white crystalline mass, *hydrate of chloral.* It is fused by a gentle heat, agitated in a stoppered bottle with twice or thrice its volume of oil of vitriol, the mixture gently warmed when impure chloral rises to the surface, as a colorless oily stratum, which is removed, boiled to expel chlorohydric acid and alcohol, distilled with its own volume of oil of vitriol, and finally rectified with finely powdered quicklime, the distillation being stopped as soon as the surface of lime is dry.

Prop. A mobile oily liquid of a peculiar penetrating, agreeable smell, causing a flow of tears; taste at first slight, afterwards acrid; spec. grav. at $65^\circ = 1.502$; boils at 202° ; miscible with ether and alcohol, dissolves sulphur, phosphorus, and iodine apparently without change. Form. $C_4HCl_3O_3$, or $C_4Cl_3O + HO$.

Hydrate of Chloral consists of 1 eq. chloral + 2 eq. water. (*Dumas.*) Chloral mixed with water dissolves at first, and is soon converted into a semi-solid mass of fine needles, translucent, soluble in more water, crystallizing in large rhomboidal crystals by the evaporation of this solution in vacuo over sulphuric acid. The solution of chloral has the same taste and odor, is neutral, and does not precipitate nitrate of silver. The dry hydrate may be distilled without change. When heated with caustic alkalis, it is resolved into perchloride of formyl, alkaline formiate and chloride.

Insoluble Chloral. Chloral, like aldehyde, cannot be kept without change. After some time it solidifies into a white translucent mass like porcelain, called insoluble chloral, whether in close or open vessels. There is no disengagement of gas and no gain of weight. It is most readily formed, when alcohol charged with chlorine, as in the preparation of chloral, is mixed with oil of vitriol and allowed to stand in open vessels; the upper oily stratum soon solidifies, and the degree of its solidification furnishes the best test of the progress of the operation. Insoluble chloral appears to be partially decomposed by washing with water, and after washing with alcohol and water dries

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to a white powder, very insoluble in water, alcohol, and ether. When distilled, it yields chloral, which solidifies again in an amorphous state. Treated with potassa, it yields formiate of potassa and perchloride of formyl, with chloride of potassium. Form. $C_{12}H_4Cl_8O_7$. *Dumas.*

CHLORINE. Syn. Oxidized, oxygenated, dephlogisticated, Muriatic, or Marine acid. Common salt, chloride of sodium, was known from the earliest times, from which the alchemists first obtained muriatic or chlorohydric acid. Chlorine was discovered by Scheele in 1774, and regarded as oxygenated muriatic acid until Gay-Lussac and Thénard, in 1809, suggested that it might be viewed as an element, which was more firmly established by Davy, 1810, and called by him chlorine. Berthollet observed and applied the bleaching power of chloride of alkali. The latest discoveries are those of Millon, which nearly complete our knowledge of the oxides of chlorine.

Chlorine is a very abundant element, constituting $\frac{3}{4}$ of all the common salt in sea-water, rock-salt, &c., and occurs both in the animal and vegetable kingdoms, as an essential constituent.

Sym. Cl. *Equiv.* 35.47 (442.65, O. = 100). Berzelius and others halve the eq. making the atom of chlorine 17.74. Dumas and others, following Proust's theory, that the equivalents of all elements are simple multiples of hydrogen, make the equiv. of chlorine 36; but the recent experiments of Laurent, Marignac, and Pelouze confirm and establish the former determination of Berzelius.

Prep. 1. By mixing 1 pt. powdered binocide of manganese with 2—3 pts. concentrated hydrochloric acid; effervescence takes place in the cold from the escape of chlorine, but much more gas is evolved by the application of a moderate heat. It may be collected over hot water or by displacement of air in dry vessels, the tube conducting the gas reaching to the bottom, where it displaces the air. The theory of the process is $MnO_2 + 2HCl = MnCl + 2HO + Cl$. 2. By heating a mixture of binocide of manganese, common salt, and dilute sulphuric acid; $MnO_2 + NaCl + 2SO_3 = MnO, SO_3 + NaO, SO_3 + Cl$. This process is employed in the manufacture of BLEACHING POWDER. To obtain chlorine free from muriatic acid, it should be passed through a little water.

Prop. A yellowish green colored gas, with an astringent taste, and a disagreeable highly suffocating odor, exciting spasm and irritation of the glottis, even when diluted with air. According to Davy, 100 cubic inches of dry chlorine at 30 B. and 60 F. weigh between 76 and 77 grains. Gay-Lussac and Thénard found the density of pure and dry chlorine to be 2470, which gives 76.599 grains as the weight of 100 cubic inches at 60° F. and 30 B. Spec. grav. by calculation = 2454.3. Its refractive power = 2.623. Light does not act on dry chlorine; but if water be present, the gas decomposes it, uniting with hydrogen to form hydrochloric acid, while oxygen is set free. It unites with some substances with evolution of heat and light, and is hence termed a supporter of combustion. On plunging a lighted taper into chlorine, it burns for a short time with a small

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red flame, and emits a large quantity of smoke. Phosphorus takes fire in it spontaneously, emitting a pale white light. Several of the metals, such as tin, copper, arsenic, antimony, zinc, Dutch metal, &c., in powder or fine leaves, likewise inflame in it spontaneously. In all these cases the hydrogen, metal, phosphorus, &c., unite with chlorine. It has a powerful attraction for hydrogen, a striking example of which is its power of decomposing water by the action of light, or at a red-heat; and the same effect is produced on most compound substances, of which hydrogen is an element, especially organic. When chlorine, water, and some other body which has an affinity for oxygen, are brought together, water is usually resolved into its elements, its hydrogen attaching itself to the chlorine, and its oxygen to the other body. Thus chlorine is indirectly a powerful oxidizing agent. It is likewise capable of replacing the hydrogen it eliminates from many organic substances, equiv. for equiv. See *SUBSTITUTION, CHLORACETIC ACID, &c.*

One of the most important properties of chlorine is its bleaching power; animal and vegetable colors are speedily and permanently removed by chlorine; but Davy proved that it cannot bleach unless water is present. See *BLEACHING.*

Chlorine is likewise useful for the purpose of fumigation, by destroying the volatile principles given off by putrefying animal matter; and it probably acts in a similar way on contagious effluvia. Chloride of lime or soda is used for this purpose.

Liquid Chlorine. 1. The gas may be cooled to -40° without change, but a pressure of about 4 atmospheres condenses the dry gas to a liquid. 2. Hydrate of chlorine heated in a sealed tube divides into two liquid strata, the upper being water, the lower chlorine. 3. The strongest muriatic acid and binoxide of manganese is introduced into one end of a sealed syphon tube, while the other end is cooled 18° lower; it distills over. 4. $\frac{3}{4}$ ths of the longer leg of a syphon tube is filled with a mixture of previously fused bisulphate of potassa, dry salt, and binoxide of manganese, and a $\frac{1}{2}$ inch layer of chloride of calcium placed over it, and the shorter leg sealed; the longer leg is placed in a gun barrel and heated, while the shorter is cooled. It is yellow or greenish yellow, very fluid; spec. grav. 1.33; refracting light a little less than water; a non-conductor of electricity; rising suddenly in vapor when the tube is opened, leaving a small portion of the liquid from the cooling of evaporation.

Chlorine Water. Water absorbs more chlorine when left at rest than when agitated. The following table of Pelouze shows the amount in volumes absorbed by 100 volumes water at different temperatures.

175 to 180 at 32°	245 to 250 at 57°
270 " 275 " 48°	200 " 210 " 86°
270 " 275 " 50°	155 " 160 " 104°
250 " 260 " $53\frac{1}{2}^{\circ}$	115 " 120 " 122°
250 " 260 " 57°	60 " 65 " 158°

To prepare chlorine water, add 3 pts. crude muriatic acid, of 1.13, diluted with 1 pt. water to 1 pt. manganese, (or a little more,) heat it

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gently and slowly, and receive the gas in 28 pts. water in a black bottle or a dark place.

Hydrate of Chlorine. A little saturated solution of chlorine, in a flask filled with the gas, and exposed to 32° — 36° , forms a pale-yellow, translucent, crystalline solid, which decomposes, by heating to 100° in a sealed tube, into chlorine water and liquid chlorine; by a slight warmth in an open vessel, into chlorine water and the gas. Form. Cl, 10 HO.

Use. Chlorine water finds a place in the Pharmacopœia. The gas formerly employed as a bleaching agent, is now rarely used, being less manageable and very injurious to operatives, its place being supplied by chloride of lime. The same salt is also used for fumigation, to remove or destroy vermin, &c. For this purpose it may be mixed with a little water to form a thick paste, then a larger quantity of water added, and finally a little vinegar or other dilute acid. A strong acid added to chloride of lime or its strong solution develops a large amount of gaseous chlorine, hence much caution is required in employing it in dwellings.

Analysis. Chlorine gas or water may be recognised by its peculiar color and odor. The chlorates, perchlorates, &c., leave chlorides by ignition, and hence the detection of chlorine in solution as a chloride is mainly sought after. Free chlorohydric acid dissolves gold by the addition of pure nitric acid, and evolves chlorine by adding to it binoxide of manganese, and heating it. To detect chlorine in soluble chlorides, add to the dilute solution nitrate of silver; the chloride of silver is insoluble in water and dilute acids; it is soluble in strong muriatic acid, but precipitates by dilution; it is readily soluble in ammonia. The cyanide of silver, which resembles the chloride, forms prussic acid with muriatic. Its separation from bromine, see under *BROMINE*; from iodine, it is separated by precipitating both by nitrate of silver, and dissolving out the chloride of silver by ammonia, in which the iodide is nearly insoluble. Chlorine is estimated quantitatively by weighing the chloride on a balanced filter, or by a careful ignition and fusion in a porcelain crucible, or the latter may be reduced by zinc, and the metallic silver weighed. When it occurs with bromine, or iodine, the relative quantities may be determined by indirect analysis, (see *ANALYSIS*, p. 167,) by precipitating them with silver, weighing them, reducing them to metallic silver, the weight of which subtracted from the weight of their compounds will give the total weight of chlorine and bromine or iodine, from which their relative quantities may be readily calculated. If chlorine, bromine, and iodine be combined with a single base, (such as sodium in mineral waters,) they may also be determined by indirect analysis, by weighing this combination, then their combination with silver, and finally their total amount from the reduced silver. A simple equation with 3 unknown quantities will give the relative quantities of each. The difference in their combining weights is such that a calculated analysis would give as accurate a result as could be attained by a complete separation.

Chlorides. Chlorine exhibits powerful affinities, not inferior to those of any other body. Metallic chlorides are formed, 1, by bringing the metal into chlorine at common temperatures, Sb, As, Bi, &c.: or by heating others in it, Na, Zn, Fe, Co, &c.; 2, by decomposing some metallic oxides, with evolution of oxygen, AgO ; or by mixing the oxide with carbon, Al_2O_3 , &c., or where moisture is present forming at the same time an oxacid of chlorine, Bleaching Powder, chlorate of potassa, &c.; 3, by solution of an oxide or metal in chlorohydric acid, which is the usual method, thus, $\text{CaO} + \text{HCl} = \text{CaCl} + \text{HO}$; 4, the insoluble chlorides are formed by precipitation.

The chlorides are solid, with the characteristic color of the salts of the metal, soluble in water, except chlorides of silver, gold, and platinum, dichlorides of mercury and copper; they are fusible, mostly volatile at high temperatures; gold and platinum lose all their chlorine by heat, chloride of copper one half; chlorides of iron, manganese, and the alkalino-earth metals, especially magnesia, are partly or wholly changed into oxides. The stronger acids, sulphuric, phosphoric, arsenic, and also boracic decompose the chlorides at common or higher temperatures.

Chlorine and Hydrogen. 1. *Chlorohydric acid.* Syn. Marine, Muriatic, Hydrochloric acid, Spirit of Salt; Ger. Chlorwasserstoffsäure, Salzsäure. Equal measures of chlorine and hydrogen unite explosively by the sun's rays, sometimes in diffused day-light, by flame, by a greater or less heat, by the electric spark, by the decomposition of water and of numerous organic and many inorganic bodies, containing hydrogen. *Prep.* The gas is prepared by adding 1

pt. oil of vitriol to 1 pt. common salt in a retort, heating gradually and gently, and receiving the gas over mercury, $\text{NaCl} + \text{SO}_3, \text{HO} = \text{NaO}, \text{SO}_3 + \text{HCl}$. *Prop.* A colorless gas, with a pungent odor and an acid taste; irrespirable, exciting violent spasm of the glottis, when diluted with air; far less irritating than chlorine; extinguishes burning bodies, and is not itself inflammable; under a pressure of 40 atmospheres, and at a temperature of 50° , it is liquid; spec. grav. 1269; refractive power = 1.527 (air = 1); not chemically changed by heat; readily decomposed by galvanism, hydrogen appearing at the —, and chlorine at the + pole; a mixture of oxygen and chlorohydric gases electrified, the oxygen unites with the hydrogen of the acid to form water, and chlorine is set free. It has a powerful attraction for water, a dense white cloud appearing when it escapes into the air; a piece of ice put into a jar of the gas over mercury liquefies instantly, while the gas disappears in a few seconds; on opening a long wide jar of the gas under water, absorption takes place so instantaneously that the water is forced up into the jar as into a vacuum; increase of temperature takes place during the absorption; 1 vol. water at 40° absorbs 480 vols. of the gas, and the solution has a spec. grav. = 1.2109. *Composition:*

	H=1.	O=100.	In 100 pts.
Cl.....	35.47	442.64	97.26
H.....	1	12.5	2.74
	36.47	455.14	100

Formula, HCl . Berzelius and others, write the atom HCl , giving it $\frac{1}{2}$ the above combining weight, and call the double atom, H_2Cl_2 , an equivalent, which corresponds to our HCl .

MANUFACTURE OF MURIATIC ACID.

Fig. 37.

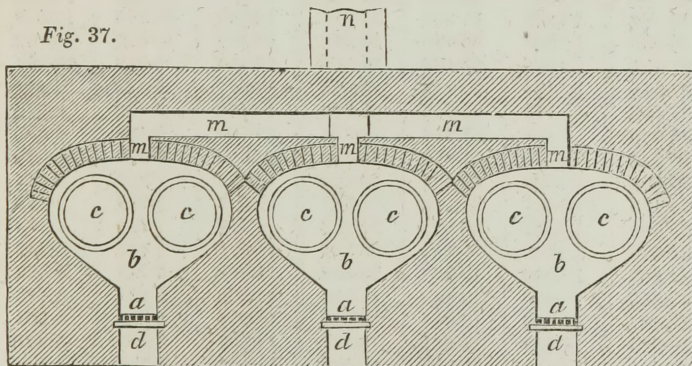
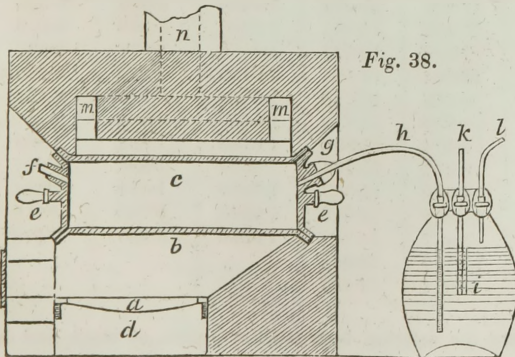


Fig. 38.



Commercial muriatic acid is manufactured from oil of vitriol and common salt in iron retorts, several of which are arranged in a bench or stack, as shown in figs. 37 and 38. Fig. 37 is a transverse section of a stack, and 38 a longitudinal section of one of the cylinders, with a condensing carboy attached. *a*

is the grate; *b*, a fireplace, in which two iron cylinders, *c, c*, are set alongside of each other. They are $5\frac{1}{2}$ feet long, 20 inches in diameter, about $\frac{1}{4}$ of an inch thick, and take 1.6 cwt. of salt for a charge; *d* is the ashpit; *ee* are cast-iron lids, for closing both ends of the cylinders; *f* is a tube in the posterior lid, for pouring in the sulphuric acid; *g* is another tube, in the anterior lid, for the insertion of the bent pipe of hard glazed stone-ware *h*; *i* is a three-necked stone-ware carboy; *k* is a tube of safety; *l* a tube of communication with the second carboy; *mm, m* are the flues leading to the chimney *n*.

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After the salt has been introduced, and the fire kindled, 83½ per cent. of its weight of sulphuric acid, of spec. grav. 1·80, should be slowly poured into the cylinder through a lead funnel, with a syphon-formed pipe. The three-necked carboys may be either placed in a series for each retort, like a range of Woulfe's bottles, or all the carboys of the front range may be placed in communication with one another, while the last carboy at one end is joined to the first of the second range; and thus in succession. They must be half-filled with cold water; and when convenient, those of the front row at least, should be plunged in an oblong trough of running water. The acid which condenses in the carboys of that row is apt to be somewhat contaminated with sulphuric acid, muriate of iron, or even sulphate of soda; but that in the second and third will be found to be pure. In this way 100 pts. of sea-salt will yield 130 pts. of muriatic acid, of spec. grav. 1·19; while the sulphate of soda in the retort will afford from 208 to 210 of that salt in crystals.

It is proper to heat all the parts of the cylinders equally, to insure the simultaneous decomposition of the salt, and to protect it from the acid; for the hotter the iron, and the stronger the acid, the less erosion ensues.

The fire should be briskly kindled, but lowered as soon as the distillation commences; and then continued moderate till the evolution

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of gas diminishes, when it must be heated somewhat strongly to finish the decomposition. The iron door is now removed, to extract the sulphate of soda, and to recommence another operation. The sulphate ought to be white and uniform, exhibiting in its fracture no undecomposed sea-salt. *Ure.*

Instead of the form of the carboy in fig. 38, it may be cylindrical, with only 2 necks, into one of which the exit tube *h* opens, while the tube *l* passes from the other. In this case *h* does not pass beneath the surface of the liquid in the carboy, and hence there is no necessity for the safety tube *k*; for the affinity of the gas to the water is so strong that it will be fully saturated by it. With this arrangement, when the first carboys in the series are saturated they are removed, and replaced by the following ones, or they are emptied and recharged with water.

Commercial chlorohydric acid has a yellow color, and is always impure, its usual impurities being nitric, sulphuric, and sulphurous acids, chlorine, arsenic, oxide of iron, &c. The presence of chlorine may be inferred if the acid dissolves gold leaf; iron is detected by prussiate of potassa, sulphuric acid by chloride of barium, after dilution with 3 or 4 pts. water.

The following table by Ure represents the strength of muriatic acid of different densities:

Specific gravity.	Chlorine.	Muriatic gas.	Specific gravity.	Chlorine.	Muriatic gas.	Specific gravity.	Chlorine.	Muriatic gas.
1·2000	39·675	40·777	1·1328	26·186	26·913	1·0637	12·697	13·049
1·1982	39·278	40·369	1·1308	25·789	26·505	1·0617	12·300	12·641
1·1964	38·882	39·961	1·1287	25·392	26·098	1·0597	11·903	12·233
1·1946	38·485	39·554	1·1267	24·996	25·690	1·0577	11·506	11·825
1·1928	38·089	39·146	1·1247	24·599	25·282	1·0557	11·109	11·418
1·1910	37·692	38·738	1·1226	24·202	24·874	1·0537	10·712	11·010
1·1893	37·296	38·330	1·1206	23·805	24·466	1·0517	10·316	10·602
1·1875	36·900	37·923	1·1185	23·408	24·058	1·0497	9·919	10·194
1·1857	36·503	37·516	1·1164	23·012	23·650	1·0477	9·522	9·786
1·1846	36·107	37·108	1·1143	22·615	23·242	1·0457	9·126	9·379
1·1822	35·707	36·700	1·1123	22·218	22·834	1·0437	8·729	8·971
1·1802	35·310	36·292	1·1102	21·822	22·426	1·0417	8·332	8·563
1·1782	34·913	35·884	1·1082	21·425	22·019	1·0397	7·935	8·155
1·1762	34·517	35·476	1·1061	21·028	21·611	1·0377	7·538	7·747
1·1741	34·121	35·068	1·1041	20·632	21·203	1·0357	7·141	7·340
1·1721	33·724	34·660	1·1020	20·235	20·796	1·0337	6·745	6·932
1·1701	33·328	34·252	1·1000	19·837	20·388	1·0318	6·348	6·524
1·1681	32·931	33·845	1·0980	19·440	19·980	1·0298	5·951	6·116
1·1661	32·535	33·437	1·0960	19·044	19·572	1·0279	5·554	5·709
1·1641	32·136	33·029	1·0939	18·647	19·165	1·0259	5·158	5·301
1·1620	31·746	32·621	1·0919	18·250	18·757	1·0239	4·762	4·893
1·1599	31·343	32·213	1·0899	17·854	18·349	1·0220	4·365	4·488
1·1578	30·946	31·805	1·0879	17·457	17·941	1·0200	3·968	4·076
1·1557	30·550	31·398	1·0859	17·060	17·534	1·0180	3·571	3·670
1·1536	30·153	30·990	1·0838	16·664	17·126	1·0160	3·174	3·262
1·1515	29·757	30·582	1·0818	16·267	16·718	1·0140	2·778	2·854
1·1494	29·361	30·174	1·0798	15·870	16·310	1·0120	2·381	2·447
1·1473	28·964	29·767	1·0778	15·474	15·902	1·0100	1·984	2·039
1·1452	28·567	29·359	1·0758	15·077	15·494	1·0080	1·588	1·631
1·1431	28·171	28·951	1·0738	14·680	15·087	1·0060	1·191	1·224
1·1410	27·772	28·544	1·0718	14·284	14·679	1·0040	0·795	0·816
1·1389	27·376	28·136	1·0697	13·887	14·271	1·0020	0·397	0·408
1·1369	26·979	27·728	1·0677	13·490	13·863			
1·1349	26·583	27·321	1·0657	13·094	13·456			

The following table by Thomson shows the relation between the equivs. of water and dry
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acid, of different specific gravities. It will be observed that the numbers are a little higher than those of Ure.

Atoms of acid.	Atoms of water.	Real acid in 100 of the liquid.	Specific gravity.
1	6	40.659	1.203
1	7	37.000	1.179
1	8	33.945	1.162
1	9	31.346	1.149
1	10	29.134	1.139
1	11	27.206	1.1285
1	12	25.517	1.1197
1	13	24.026	1.1127
1	14	22.700	1.1060
1	15	21.512	1.1008
1	16	20.442	1.0960
1	17	19.474	1.0902
1	18	18.590	1.0860
1	19	17.790	1.0820
1	20	17.051	1.0780

Pure Muriatic acid. Prep. 1. This may be procured by adding 5 pts. oil of vitriol, diluted with 1 pt. water and cooled, to 3 pts. common salt in a retort or flask connected with a Woulfe's apparatus of 3 flasks, in the first and third of which is a little water, in the second about 5 pts. water. A very gentle heat is gradually applied; $\text{NaCl}, \text{HO} + 2\text{SO}_3 = \text{NaO}, 2\text{SO}_3 + \text{HCl}$. 2. In a similar apparatus add a little binoxide of manganese to one part of the strong muriatic acid of commerce to convert any sulphurous into sulphuric acid, and a little protochloride of iron to absorb chlorine; then by means of an S tube pour 2 pts. oil of vitriol of 1.834 into the retort, and gradually heat to boiling; the oil of vitriol retains the water. *Lem- bert.*

Prop. Concentrated and pure chlorohydric acid is a colorless liquid, emitting white vapors when exposed to the air, is intensely sour, reddens litmus paper strongly, and neutralizes alkalies; combines with water in every proportion, causing an increase of temperature; refractive in direct ratio to density; freezes at -60°F. ; and boils at 110° , or a little higher, giving off chlorohydric gas; a strong acid becomes weaker by boiling, a weak acid stronger, that acid of 1.1 containing 20 per cent. gas, or HCl, 16 HO, having a constant boiling point. See ABSORPTION, p. 4.

Use. Muriatic acid is largely employed in the arts for dissolving metals, (tin-salts, &c.,) earths (bones, &c.); its uses chiefly depending on the strong affinities of chlorine, and the solubility of most chlorides. To the theoretic chemist it is one of the most invaluable reagents on the same grounds, being his principal acid solvent.

2. *Chlorohydrate of Nitric Oxide.* Reinsch obtained this compound by distilling sulphate of nitric oxide and common salt, and by direct union of the two gases. It is a greenish yellow oily liquid, much less acid and acrid than muriatic acid, and exceedingly volatile, even at 46° . *Chem. Gaz.* ii. 85.

3. *Bichloride of Hydrogen.* Millon's bichloride requires farther experiment.

Chlorine and Oxygen. 1. *Hypochlorous acid.* *Ger.* Unterchlorige Säure. *Prep.* In a free state.

CHLORINE.

1. Introduce yellow oxide of mercury, precipitated and heated to 530° or 570° , into a glass tube, pass dry chlorine slowly through it, and receive the gas in dry jars or into water; $\text{HgO} + 2\text{Cl} = \text{HgCl} + \text{ClO}$, *Pelouze, Balard*. 2. Pass chlorine into water containing suspended carbonate of lime or sulphate of soda, and gently distil off the acid. *Williamson, Ch. Soc. Dec. 1844.* In combination. Chlorine passed through hydrous alkali forms chloride and hypochlorite.

Prop. An orange-yellow gas, darker than chlorine, of a somewhat similar odor, condensing to a blood-red liquid by a temperature of -4° (a mixture of salt and snow). The liquid resumes its gaseous state at 62° to 68° , but is very explosive, often decomposing by shaking or pouring, not only rising in vapor but changing into chlorine and oxygen; potassium, phosphorus, arsenic, and powdered antimony oxidize often with explosion in the gas or liquid. The gas is easily decomposed with explosion by warmth, without explosion in sunlight; spec. grav. = 2.977, by calculation 3.30.

Water at 32° absorbs 200 times its volume of the gas, or 100 pts. water 77.36 pts. of the gas, whence this solution is $\text{ClO} + 6\text{HO}$. The solution has the same odor as bleaching salt, but far more intense: it has a very caustic action on the skin; arsenic burns in it with a blue flame; antimony decomposes it; muriatic acid, ammonia, oxalic acid, produce violent effervescence; arsenious acid becomes oxidized in it with slight detonations forming arsenic acid; sulphuret of lead is quickly converted into sulphate of lead even by very dilute solutions, which may therefore be recommended for washing white oil colors which have become brown; salts of the protoxide of manganese are immediately changed into peroxide of manganese; from lead salts brown peroxide is precipitated, and these reactions may be employed to advantage in obtaining the two peroxides in a state of very fine division. In the case of peroxide of lead a dilute solution of the basic acetate is most to be recommended. Chloride of silver decomposes the aqueous acid, and when muriatic acid is added in drops to the aqueous acid at a temperature of 36° to 38° , a very abundant crop of crystals of the hydrate of chlorine is obtained. *Pelouze in Comptes Rendus*, xvi. p. 43.

The aqueous acid is readily decomposed by heat and light, especially by the sun's rays; the more dilute the less rapid the decomposition; chlorine and oxygen are evolved and chloric acid remains. The powerful affinities of both chlorine and oxygen for other substances, and the feeble affinity which holds themselves together, indicate clearly that a vast number of substances, both inorganic and organic will readily decompose hypochlorous acid; giving rise chiefly to oxides, but also to oxides and chlorides. It is hence a most powerful bleaching agent. Form. $\text{ClO} = 43.48$.

Hypochlorites. They are formed, 1, by solution of oxides in the acid; 2, by passing 2 eq. chlorine into a solution of 2 eq. caustic or carbonated alkali, or into caustic alkaline earths; a chloride and hypochlorite are formed; $2\text{KO} + 2\text{Cl} = \text{KCl} + \text{KO}, \text{ClO}$. It is in this manner that BLEACHING POWDER is formed. The hypo-

CHLORINE.

chlorites consist of 1 eq. base and 1 eq. oxide; MO, ClO_2 ; they have a caustic, astringent taste; decompose by light, especially by the sun's rays, into chloride and chlorate, usually evolving oxygen; the decomposition is more or less hindered in proportion to excess of alkali. They are powerful oxidizers, even when mixed with chlorides, such as bleaching powder, changing the metalloids and their lower oxides into the highest oxides or acids; the sulphuretted metals are changed into sulphates, the metals themselves mostly into oxychlorides, tin, zinc, antimony, copper, mercury, silver, or its oxide, becomes chlorides. They have powerful bleaching properties, unless alkali be in excess, when an acid develops its power, even the feeblest; the feeble and the stronger acids diluted develop hypochlorous acid; the more concentrated eliminate chlorine. Hence a dilute solution of bleaching salt treated with sulphuric acid retains its bleaching power for some time.

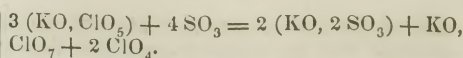
2. *Chlorous acid.* *Ger.* Chlorige Säure. This acid, long since supposed to exist in combination, in bleaching liquids prior to the formation of chloric acid, has been thus isolated by Millon. 1. Mix 1 eq. arsenious acid with 1 eq. chloric acid in solution and distil; $\text{AsO}_3 + \text{ClO}_5 = \text{AsO}_5 + \text{ClO}_3$. 2. Mix 20 pts. finely powdered and moistened chlorate of potassa with 15 pts. fine arsenious acid, pour on the mixture 60 pts. pure nitric acid, of spec. grav. 1.327, previously diluted with 20 pts. water, fill it into a flask until nearly full, which connect with a tube, and heat it from 113° to 122° , but not beyond 122° , for fear of explosion. 3. Heat in a similar manner 1 pt. tartaric acid, 4 pts. chlorate of potassa, 6 pts. nitric acid, and 8 pts. water. The gas may be received in dry vessels or in water.

Prop. A deep greenish yellow gas, with an odor closely resembling that of hypochlorous acid, and, like it, condensable to a red liquid by a greater cold, decomposing by a slight explosion at 135° into chlorine and oxygen; bleaches indigo-blue solution; 1 vol. water at 68° dissolves 6 vols. gas, with a gold-yellow color, caustic taste, producing a yellow spot on the skin; the gas and solution are both decomposed by sunlight; the dry gas does not act on the metals, except mercury; the aqueous acid acts on them, forming oxychlorides, chlorates, and chlorides; gold, platinum, and antimony are not acted on; it does not unite for some minutes. It is decomposed by few organic substances. *Form.* ClO_3 , eq. = 59.5.

Chlorites. Formed by direct union. They are all decomposed by dilute nitric acid, chlorous acid being set free; some cannot be concentrated beyond a certain point without decomposition; soda and baryta form also bichlorites, with deep red solutions, uncrystallizable; the salts of baryta, strontia, lead, and silver are crystallizable. *Form.* MO, ClO_3 .

3. *Hypochloric acid.* *Syn.* Peroxide of Chlorine, Chlorous acid. *Prop.* Heat 1 pt. chlorate of potassa in a glass retort nearly to fusion, pour over it when cold 4 pts. oil of vitriol, and heat it gradually in a water-bath in the space of 3 hours from 54° to 212° , (*Stadion*;) or heat the same mixture without previously heating the chlorate, and with less oil of vitriol. (*Davy*.)

CHLORINE.



Prop. A lively greenish yellow gas, brighter than chlorine, and less suffocating, with an aromatic odor; spec. grav. = 2.336; condenses in a syphon tube by its own pressure to a transparent, yellow liquid, of spec. grav. 1.5; first reddens, then bleaches litmus paper; 1 vol. water dissolves 7 vols. of the gas, with the same color, giving off white fumes in the air; unchangeable in the dark, rapidly in sunlight; the solution changes by light into chlorine and chloric acid; forms with alkali a chlorate and chlorite, (*Millon*;) a chlorate and chloride, (*Davy* and *Stadion*;) acids evolve hypochloric from these solutions, (*Martens*.) *Form.* ClO_4 , eq. = 67.5.

4. *Chloric acid.* *Syn.* Hyperoxymuriatic acid. *Ger.* Chlorsäure. *Prop.* 1. Expose 3 in solution, to light; heat gently to expel chlorine. 2. Add dilute sulphuric acid to a solution of chlorate of baryta, till the filtered liquid is precipitated neither by chlorate of baryta nor by sulphuric acid. 3. Mix a hot solution of chlorate of potassa with fluosilicic acid, filter, mix with silica, and evaporate below 86° , in vacuo, over oil of vitriol.

Prop. Only known in solution. It reddens vegetable blues, has an acid taste; possesses no bleaching properties, which distinguishes it from 1, 2, and 3; gives no precipitate in a solution of nitrate of silver; its solution may be concentrated by a gentle heat, and then it sets fire to paper and other dry organic matter, and converts alcohol into acetic acid; when heated above 104° , part of the acid is resolved into chlorine and oxygen, while another portion is converted into perchloric acid, and passes over into the receiver in the form of a dense colorless liquid. (*Serullas*.) It is easily decomposed by deoxidizing agents; sulphurous acid forms sulphuric acid and evolves chlorine; by sulphohydric acid water is generated, while sulphur and chlorine are set free. Chlorohydric acid decomposes it into water and chlorine. *Form.* ClO_5 ; eq. = 75.5.

Chlorates. They are formed directly by mixing the acid and oxide, or by decomposing chlorate of baryta by a sulphate or carbonate; the alkaline by passing chlorine through the solution of alkali, and separating chloride and chlorate by crystallization. They are deliquescent, except the salts of potassa, baryta, lead, mercury, and silver, nearly all crystallizable with and without crystal water; soluble in alcohol, except ammonia and strontia, the salt of baryta slightly. They are all decomposed by heat, some evolving oxygen and leaving a chloride, the alkalies, silver; or oxygen and chlorine, leaving oxide and chloride, the alkaline earths, lead, mercury, cadmium; leaving peroxide, manganese, nickel, cobalt, lead; the salts of potassa and soda, heated to a given point, separate into chloride and perchloride, evolving some oxygen, $2(\text{KO}, \text{ClO}_5) = \text{KCl} + \text{KO}, \text{ClO}_7 + \text{O}_2$. When mingled with combustibles, they explode by heat, some by friction or impact, (with phosphorus, sulphur, &c.,) some by adding oil of vitriol (with sugar, &c.). They are readily decomposed by strong acids, even by oxalic, citric, and tartaric acids, chloro-

CHLORINE.

rine, oxygen, and hypochloric acid being evolved. See *Chlorate of Potassa* under POTASSIUM. General formula, MO, ClO_5 .

5. *Perchloric acid*. Ger. Ueberchloresäure. Prep. 5 pts. of finely pulverized perchlorate of potassa are put into a retort, and 10 pts. of sulphuric acid, of spec. grav. 1.848, diluted with 1 pt. of distilled water are added. A receiver is adjusted without any lute of paper or other organic matter; if any be used it should be of asbestos. As hyperchloric acid is volatilized at 284° , it is better not to let the mixture boil; by this means sulphuric acid is prevented from passing over. If the residue in the retort becomes colorless and no more drops pass over, although the temperature is high, then the operation is finished. In this way 3 pts. of impure acid are obtained, spec. grav. 1.455. If the distillation has been conducted too rapidly it contains sulphuric acid, and has a higher specific gravity. To free it from chlorine and sulphuric acid, it is shaken with a small excess of sulphate of silver, and the filtered solution is mixed with newly precipitated carbonate of baryta until all the sulphuric acid is saturated and only a little hyperchlorate of baryta is formed. The filtered acid, containing silver and baryta, is then distilled in an oil-bath at a gentle heat, and the water which passes over first received by itself until it has an acid reaction. The distillation may be conducted to dryness. The acid thus obtained is pure, colorless, and transparent. Its specific weight lies between 1.117 and 1.824; it is oily like sulphuric acid. 5 pts. perchlorate yield 1.5 pts. of the pure acid. (*Nativelle in Chem. Gaz.* i. 17.) To prepare the crystallized acid, distil the concentrated liquid acid with oil of vitriol at a gentle heat; it deposits in the neck of the retort and in the receiver.

Prop. The solid acid, is a white, crystalline mass, or long 4-sided prisms, fusing at 113° , fumes in the air, is very deliquescent. The liquid acid is colorless, oily when concentrated, inodorous, agreeably acid, volatilizes at 284° , is not decomposed by sunlight, sulphuretted hydrogen, sulphurous or muriatic acid, or when heated with alcohol; paper imbued with it does not inflame spontaneously. In general, it ex-

hibits greater stability than would be supposed from its composition, and the nature of the other oxacids of chlorine. Formula, ClO_7 , eq. = 91.5.

Perchlorates. Crystallizable, most of them deliquescent, very soluble in water, and soluble in alcohol, those not deliquescent are the salts of potassa, ammonia, and protoxides of lead and mercury. When heated to redness, they decompose in a manner similar to the chlorates, but less easily, and their explosiveness with combustibles is less violent; they are distinguished from the chlorates by not acquiring a yellow tint on the addition of hydrochloric acid; the salt of potassa is the most insoluble perchlorate, and hence perchloric acid precipitates potassa from its salts like tartaric acid. The solubility in alcohol of the salt of baryta, soda, and oxide of silver, and the insolubility of the salt of potassa, may be employed for the separation of potassa and soda in analysis. Neutral salts, MO, ClO_7 .

Other compounds of chlorine see under the several elements.

CHLORITE. *Min.* Syn. Chlorite slate, Ripidolite, Chlorophæite, Talc Zographique, *H.* *Descrip.* Cryst. Hexagonal; cleavage parallel with the base and highly perfect; it also occurs in radiated forms, and massive, of a granular texture, or earthy. $H. = 1.5$. $G. = 2.65-2.85$. Color emerald-green, seen in the direction of the axis, and yellowish or hyacinth-red, at right angles with it; massive varieties olive-green; lustre vitreous to pearly; transparent, subtranslucent; laminæ not elastic.

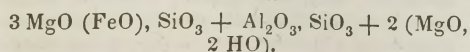
Behavior. Yields water in a closed tube; fuses generally with difficulty on charcoal to a black bead; soluble in borax, giving an iron reaction; slightly soluble in mic. salt, leaving a skeleton of silica; does not unite with soda, but on the edges. Oil of vitriol decomposes thin laminæ; chlorohydric acid scarcely acts on it before ignition, readily after.

Analysis. 1. *Chlorite* from Achmatowsk by v. Kobell; 2, by Varrentrapp; 3, from Schwarzenstein by v. Kobell; 4, from Zillerthal by Brühl; 5, Ripidolite from Greiner in Zillerthal; 6, from Rauris by v. Kobell; 7, from St. Gotthardt by Varrentrapp.

	1.	2.	3.	4.	5.	6.	7.
Silica.....	31.14	30.376	32.68	31.466	26.51	26.06	25.367
Alumina.....	17.14	16.966	14.57	16.666	21.81	18.47	18.496
Magnesia.....	34.40	33.972	33.11	32.564	22.83	14.69	17.086
Protoxide of iron.....	3.85	4.374	5.97	5.974	15.00	26.87	28.788
Protoxide of manganese..	0.53	—	0.28	0.011	—	0.62	—
Water.....	12.20	12.632	12.10	12.425	12.00	10.45	8.958
	99.26	98.310	98.71	99.106	98.15	97.16	98.698

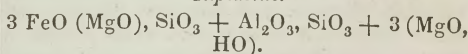
In Nos. 1, 3, and 6 there was an undecomposed residue, amounting in 6 to $2\frac{1}{4}$ per cent. Nos. 1—4 are Chlorite, No. 5—7 are Ripidolite. Some assume an aluminate in chlorite, but the following formulæ of Varrentrapp appear simpler.

Chlorite.



CHLORITE-SLATE.

Ripidolite.



Local. Chlorite forms extensive strata, chiefly constituting the Chlorite slate; it also occurs in ferruginous gneiss, &c., often replacing mica.

CHLORITE-SLATE. *Geol.* A so-called Primary formation, of a slaty structure, and

CHLORITOID.

abounding in chlorite, which seems to occupy the place of mica in other formations. An analysis of a chlorite-slate from Tyrol by Varrentrapp gave

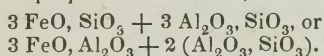
Silica.....	31.54
Alumina.....	5.44
Magnesia.....	41.54
Peroxide of iron.....	10.18
Water.....	9.32
	98.02

It resembles talcose slate, is less soapy to the touch, and has a darker green color.

CHLORITOID. *Min.* Massive, foliated, curved; of a greenish black color. *H.* = 5.5. *G.* = 3.55. Before the blowpipe it is infusible, but becomes darker; soluble perfectly in borax and mic. salt, giving a strong iron reaction. *Analysis.* 1. By Erdmann; 2, by v. Bonsdorff.

	1.	2.
Silica.....	24.90	27.48
Alumina.....	46.20	35.57
Protoxide of iron.....	28.89	27.05
Protoxide of manganese..	—	0.30
Magnesia.....	—	4.29
Water.....	—	6.95
	99.99	101.64

The two are evidently different minerals. Erdmann proposes the formula,



It was found at Koroibrod in the Ural.

CHLOROFORM. *Syn.* Perchloride of Formyl. *Prep.* 1. Chloral is mixed with milk of lime, potassa, or barytic water, and distilled; the dense liquid is repeatedly agitated with water, and then with about 6—8 times the volume of the liquid of sulphuric acid; the chloroform is drawn off from the surface, and finally distilled over baryta. 2. Mix together 1 pt. bleaching powder, 3 pts. water, and $\frac{1}{2}$ — $\frac{3}{4}$ pts. alcohol, and distil. 3. Acetone distilled with bleaching powder also yields it abundantly.

Prop. A transparent colorless liquid, of an ethereal odor and taste; spec. grav. = 1.480; boils at $141\frac{1}{2}^\circ$; spec. grav. of vapor = 4.199; not inflammable; its vapor passed over red-hot iron or copper is entirely decomposed, forming a metallic chloride covered with charcoal; decomposed by lime at a dull red-heat; not decomposed by potassium, but when the latter is heated in its vapor it burns with an explosion, chloride of potassium being formed and charcoal deposited; when long boiled with the alkaline hydrates it is converted into an alkaline chloride and formate; alcohol and ether dissolve it readily, and water throws it down again; it dissolves sulphur, phosphorus, and iodine without alteration. *Form.* C_2HCl_3 , or FoCl_3 , corresponding to formic acid with all its oxygen replaced by chlorine.

CHLOROMELAN. *Min.* See **CRONSTEDTITE**.

CHLOROPAL. *Min. Descrip.* Massive and compact; earthy. *H.* = 3—4. *G.* = 1.727—1.870; (earthy varieties, the second compact;)

CHLOROPHYLLITE.

2.105 (a Ceylon specimen). Color greenish yellow and pistachio-green; opaque, translucent; brittle, with a conchoidal and splintery fracture.

Analysis. 1, Compact, 2, earthy by Bernhardt and Brandes; 3, from Ceylon by Thomson:—

	1.	2.	3.
Silica.....	46	45.00	53.00
Protoxide of iron 33	32.00	Fe_2O_3 26.04	
Magnesia.....	2	2.00	1.40
Alumina.....	1	0.75	1.80
Water.....	18	20.00	18.00
	100	99.75	100.25

Behavior. Infusible before the blowpipe, becoming black, and then brown. It gives the reaction of iron with the fluxes. The mineral analyzed by Thomson differs from the specimens from Unghwarin, Hungary, in composition and in other respects.

CHLOROPHAN. *Min.* See **FLUOR SPAR**.

CHLOROPHÆITE. *Min.* Massive, in small grains; transparent, and of a bright or dull green color; soon becoming brown and black and opaque on exposure to the air; brittle; fracture conchoidal. It consists of silica and protoxide of iron, with a little alumina, and before the blowpipe is fusible to a magnetic glass.

CHLOROPHYLL. *Ger.* Blattgrün. The green coloring principle in leaves. It is usually obtained by treating grass with boiling water, then with alcohol or ether, evaporating or mixing with water, and distilling. It is a green waxy substance, but statements vary in regard to its qualities, and we know not whether it be a fat, resin, &c. Its color appears to be easily changed to a yellow. The following experiments by Preisser throw a little light on the subject.

Some green leaves were crushed in a porcelain mortar. The green liquor which resulted from it was treated, after filtration, with a little hydrate of lead, which entirely precipitated the green matter and discolored the liquor. The lake was decomposed by sulphuretted hydrogen. The filtered liquid was without color. It was passed under a bell-glass full of mercury containing oxygen. After a few days a portion of the gas was absorbed, the liquid was colored green, and had deposited some flakes of a darker green. The absorption of the gas had taken place more especially under the influence of the solar light.

On evaporating to dryness the yellowish liquid, obtained by decomposing the lead salt by sulphuretted hydrogen, a matter is obtained having much analogy with the *Xanthophyll* of Berzelius. *Chem. Gaz.* ii. 432.

CHLOROPHYLLITE. *Min. Syn.* Esmarkite. *Descrip.* Occurs in six and twelve-sided prisms; highly foliated parallel to the base of the prism; sometimes also a prismatic cleavage more or less distinct. *H.* of basal plane 1.5—2; the lateral edges will scratch apatite. *G.* = 2.705—2.709. Color green or greenish, greenish-brown, dark olive-green; lustre of basal plane, pearly; of lateral, pearly, or greasy to imperfectly vitreous; translucent to subtranslucent; folia neither flexible nor elastic; brittle.

CHLOROSPINEL.

Behavior. Yields water before the blowpipe, and becomes bluish gray, but fuses only on the edges. With carbonate of soda, effervescence takes place, and an opaque greenish enamel is formed, which becomes darker green in the reducing flame.

Analysis. 1. From Unity, Maine, by Jackson; 2, from Brevig, Norway, by Erdmann.

	1.	2.
Silica	45.20	45.97
Alumina	27.60	32.08
Magnesia	9.60	10.32
Protoxide of iron	8.24	3.83
Protoxide of manganese ..	4.08	0.41
Water	3.60	5.49
	98.32	98.10

Traces of phosphoric acid were detected in the chlorophyllite. It is closely allied to the hydrous iolite of Bonsdorff, but contains less water. Like that, it is found associated with iolite.

Local. It often forms thin folia interlaminated with plates of iolite in the hexagonal prisms of this mineral, and sometimes appears to graduate into iolite. The C. of Jackson occurs abundantly in large prismatic and tabular crystals at Neal's mine in Unity, Maine, associated with hornblende rocks containing iron and copper pyrites; with iolite at Haddam, Connecticut. The Esmarkite of Erdmann is found in granite near Brevig in Norway. *Dana.*

CHLOROSPINEL. *Min.* See SPINEL.

CHOCOLATE. *Tech.* The kernel of the *Theobroma Cacao* ground to a fine powder and made into a paste, which is formed into cakes and hardens. It is sometimes mixed with sugar, and a flavor often imparted to it by vanilla, cinnamon, &c. Adulterations are flour or starch, and red coloring matter. The former is innocent, and the latter may be, but both should be abandoned. See CACAO.

CHOLANIC, CHOLIC, CHOLINIC ACIDS. See under BILE.

CHOLESTERIN. *Ger.* Gallenfett. Found in the blood, brain, and bile of animals. It is most easily prepared from gall-stones, by dissolving them in boiling alcohol, filtering hot, and cooling slowly; the crystals pressed from the mother-liquor are recrystallized several times from alcohol. White, pearly scales or leaves, inodorous and tasteless, heavier than water when fused, fuses at 279°, volatilizes in close vessels; soluble in 9 pts. boiling alcohol of 0.84 and 5.55 pts. of 0.816, in 12.1 pts. ether at 32°, 3.7 at 59°, 2.2 at boiling, in wood-spirit as in alcohol, in boiling oil of turpentine slightly, soluble also in water containing 4 pts. dry soap; fuses with the fats; heated sulphuric acid with water decomposes it, nitric acid changes it into *cholesteric acid*, and artificial tannin.

Heated with caustic potassa to 266°, and treated with ether, the latter dissolved unaltered cholesterin and a resinous substance; the residue dissolved in water, and treated with chlorohydric acid, a yellow substance rises to the surface, of a resinous character, which is soluble in ether, alcohol, and caustic and carbonated alkalis. If the air have not

CHONDRODITE.

free access, more of the resin is formed, but the latter is changed into the acid by a strong heat and free access of air. (*J. Lawrence Smith.*) Smith concludes that cholesterin is one of a class of bodies containing spermaceti, ambrein, ethal, &c. See AMBREIN and CETEN. Form. $C_{38}H_{73}O$, or $C_{36}H_{72}O$.

Cholesteric acid. Cholesterin is heated with its own weight of nitric acid till no more nitric oxide is disengaged; the yellow acid separates, and when the acid liquid is diluted with water an additional quantity of it separates. The acid is repeatedly washed with water and crystallized from alcohol. Cholesteric acid has a yellow color in mass; from its alcoholic solution white needles; taste slight; lighter than water; it reddens litmus; melts at 136°; when distilled it undergoes decomposition; slightly soluble in water, readily in alcohol, ether, and the essential, but not the fixed oils; soluble in strong acids. Its salts have more or less color. Those of potassa, soda, and ammonia are very soluble in water, and deliquescent; not crystallizable; insoluble in alcohol and ether; the other cholesterates are little or not at all soluble. C. of baryta is red; of strontia, orange; of alumina, fine red while moist, but darker when dry; of lead, brick red; when cholesterate of potassa is added to mercurous nitrate, a black precipitate falls; to mercuric nitrate a red; to copper salts an olive colored precipitate; it reduces gold solutions. Form. $C_{11}H_{19}NO_5$ (?).

CHONDRIN. *Ger.* Knorpelleim. The basis of the tissue of cartilage, as it occurs in the ribs, nose, cornea, &c. It is obtained from them like gelatin or glue, to which it bears some resemblance when dry, being softened by cold and dissolved by hot water, but is usually lighter colored. It is wholly precipitated by sulphate of alumina in thick, white flocculæ, which agglutinate; it is also thrown down by acetates of lead, protochloride of tin, perchlorides of iron, platinum, and mercury; all acids color its solution, most precipitate it, and in excess redissolve it, but vegetable and arsenic acids do not redissolve the precipitate. The precipitates by oxide of iron, alumina, and acetic acid disappear by the addition of a large quantity of common salt, or alkaline acetate. The precipitate by chlorohydric acid, redissolved in excess of acid, is not clouded by prussiate of potassa. It is insoluble in alcohol. By digestion for 24 hours with muriatic acid, and washing with water, its solution then in boiling water forms a jelly, which reacts very differently from chondrin. Chlorine passed through a solution of chondrin gives a white precipitate, which becomes sea green and hard on drying, and is composed of $C_{32}H_{26}N_2O_{14} + Cl$. *Schröder.*

Formula, $C_{16}H_{13}N_2O_7$, *Mulder*; $C_{48}H_{40}N_6O_{20}$, *Liebig*; $C_{40}H_{31}N_2O_{17}$, *Marchand*. See GELATIN.

CHONDRODITE. *Min.* Syn. Hemi-prismatic Chrisolite, *M.* Malurite, Fluosilicate of Magnesia, Brucite. *Descrip.* Cryst. Oblique Rhombic; the vert. prism = 112°. Where it presents a regular form it is generally the octohedron with the intervening 4-sided prism, but the edges are so rounded that it is rarely possible to obtain a measurement of angles with the least pretension to accuracy. I have

CHONDRODITE.

several such octahedra in my collection without the vertical prism. Cleavage not very distinct, but in such directions as to lead to the supposition that the form of the crystal as described is not the true form of the mineral. It also occurs with a granular structure. $H. = 6-6.5$. $G. = 3.118$, from New Jersey; 3.199, from Finland. Color yellow, brown, red, rarely apple-green; transparent, subtranslucent; lustre vitreous, resinous; streak white, or very slightly yellowish; fracture subconchoidal, uneven; brittle.

Behavior. In a closed tube it becomes black, burning white on charcoal without fusion; soluble in borax to a clear glass, that may be clouded by flaming; leave a skeleton of silica in mic. salt, and by a strong heat gives traces of fluohydric acid; with little soda it gives a difficultly fusible gray scoria, with more soda is infusible; with cobalt solution it assumes a feeble red tint, or, if much iron be present, a grayish brown color. Fully decomposed by oil of vitriol, developing fluohydric acid; by muriatic acid leaving gelatinous silica.

Analysis. 1. From Pargas, Finland, by D'Ohsson; 2, from New Jersey, by Seybert; 3, by Thomson; 4, from New Jersey; 5, gray-colored from Pargas; 6, yellow from Pargas; the three last by Rammelsberg.

	1.	2.	3.
Silica.....	38.00	32.66	36.00
Magnesia.....	54.00	54.00	54.64
Peroxide of iron....	5.10	2.33	3.97
Potassa.....	0.86	2.11	—
Fluoric acid.....	—	4.09	3.75
Water.....	—	—	1.62
	97.96	96.19	99.98

	4.	5.	6.
Silica.....	33.06	33.10	33.19
Magnesia.....	53.46	56.61	54.50
Peroxide of iron....	3.65	2.35	6.75
Fluorine.....	7.60	8.69	9.69
	99.77	100.75	104.13

Form. $MgFl + 2(3MgO, SiO_3)$.

Local. Found only in limestone. It occurs near Abö, in the parish of Pargas, in Finland, and at Aker and Gulsjö, in Sweden. It is found in very great abundance in the adjoining counties of Sussex, New Jersey, and Orange, New York, where it is associated with spinel, and sometimes pyroxene and corundum; also at Chelmsford, Massachusetts, and at Rossie, New York.

	1.	2.	3.	4.
Protoxide of iron..	33.00	34.7	37.0	35.0
Oxide of chromium	55.50	43.7	36.0	51.6
Alumina.....	6.00	20.3	21.5	10.0
Silica.....	2.00	2.0	5.0	3.0
	2.00	—	—	—
	98.50	100.7	99.5	99.6

In 1 the 2 per cent. is loss, in 5 the 1 per cent. is protox. of manganese, and in 6, 9, and 10 the last line is magnesia. Hence the formula is FeO, Cr_2O_3 , in which the FeO is sometimes re-

CHROMIC IRON.

CHONIKRITE. *Min.* Massive, white, slightly translucent, glistening. v. Kobell's analysis gave—

Silica.....	35.69
Alumina.....	17.12
Magnesia.....	22.50
Lime.....	12.60
Protoxide of iron	1.46
Water	9.00
	98.37

Berzelius suggests that it may be an aggregate of several minerals.

CHRISTIANITE. *Min.* See **ANORTHITE**.

CHROMATE OF LEAD. *Min.* Syn. Hemiprismatic Lead-Baryte, *M.*; Crocoisite. *Ger.* Rothbleierz. *Descrip.* Cryst. system, Oblique Rhombic. Cleavage lateral, tolerably distinct; basal, less so; surface streaked longitudinally; the faces mostly smooth and shining; imperfect crystallizations, imperfectly columnar and granular. $H. = 2.5-3$. $G. = 6-6.004$. Color various shades of hyacinth-red; lustre adamantine-vitreous; translucent; streak orange-yellow; sectile.

Behavior. Blackens in the blowpipe flame, and decrepitates if quickly heated, but may be fused to a shining slag containing globules of lead; it undergoes a partial reduction in mic. salt or borax, at the same time coloring it green. Dissolves without effervescence in nitric acid, and produces a yellow solution. Composition, PbO, CrO_3 .

Local. Siberia is the principal locality; it occurs also at Beresof, associated with gold, pyrites, galena, quartz, and Vauquelinite. In Brazil, at Conconhas do Campo, fine crystallized specimens are met with. *Dana.*

CHROMIC IRON. *Min.* Syn. Octahedral Chrome Ore, *M.*; Chromate of Iron. *Ger.* Chromenstein. Cryst. system, Regular. Usually the 8-hedron, sometimes combined with the 12-hedron. Occurs usually massive; structure granular; particles strongly coherent. $H. = 5.5$. $G. = 4.321$ of crystals, (*Thomson*); 4.498, a variety from Styria. Color between iron-black and brownish-black; lustre submetallic; opaque; streak brown; fracture uneven; brittle.

Analysis. 1. From Krieglach, in Styria, by Klaproth; 2, from Bastide de la Carrade, by Vauquelin; 3, from Isle à Vaches, on St. Domingo; and, 4, from Baltimore, by Berthier; 5, from Siberia, and, 6, from Roeraas, in Norway, by Laugier; 7, from Bare Hills, and, 8, from Chester county, Pennsylvania, by Seybert; 9 and 10, from the same, by Abich.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Protoxide of iron..	33.00	34.7	37.0	35.0	24	25.661	36.00	35.14	18.97	20.13
Oxide of chromium	55.50	43.7	36.0	51.6	53	54.080	39.51	51.56	44.91	60.04
Alumina.....	6.00	20.3	21.5	10.0	11	9.020	13.00	9.72	13.85	11.85
Silica.....	2.00	2.0	5.0	3.0	1	4.833	10.60	2.90	0.83	—
	2.00	—	—	—	1	5.357	—	—	9.96	7.45
	98.50	100.7	99.5	99.6	100	98.951	99.11	99.32	98.25	99.45

placed by MgO , and the Cr_2O_3 by Al_2O_3 , and possibly in some cases by Fe_2O_3 . *Ram.*

Behavior. Unchangeable alone, but it is rendered magnetic in the inner flame, if not so

previously; dissolves slowly, but entirely, in borax, showing the color of iron while hot, and the green of chromium when cool, particularly by the addition of tin; with a minute percentage of chrome the green color is not distinctly seen; scarcely attacked by soda, readily when fused with potash and saltpeter, giving a yellow watery solution, with the reaction of chromic acid; completely dissolved by fusion with bisulphate of potassa with a green color, or with chlorate of potassa and caustic potassa. *J. C. B. and M. H. B.*

Local. Chromic iron occurs only in serpentine rocks, forming veins, or in imbedded masses. It assists in giving the variegated color to verd-antique marble. It occurs in the Gulsen mountains, near Kraubat in Styria; also in the islands of Unst and Fetlar in Shetland; in the Department du Var in France, Silesia, Bohemia, Siberia, Norway, &c. At Baltimore, Maryland, in the Bare Hills, it occurs in large quantities, in veins or masses in serpentine; also in Montgomery county, six miles north of the Potomac; at Cooptown, Harford county, and in the north part of Cecil county, Maryland; in Chester county, &c., in Pennsylvania. It occurs both massive and in crystals at Hoboken, New Jersey, imbedded in serpentine and dolomite; at Milford and West Haven, Connecticut; in large masses in the south-western part of the town of New Fane, Vermont, and Chester and Blanford, Massachusetts. At Gibara, on Cuba, in large quantities.

CHROMIC OCHRE. *Min.* Amorphous, of a rich green color, compact and mammillary; coating serpentine at Bare Hills, Baltimore. A chromic ochre analyzed by Drappiez, from France, Duflos from Halle, and Zellner from Silesia, gave 57—64 per cent. silica, 23—30 alumina, 2—10 oxide of chrome, besides magnesia, oxide of iron, and water; it is soluble in glasses of borax and mic. salt with a green color, leaving a white residue, partially soluble in potassa-lye. It is a $\frac{2}{3}$ neutral silicate of alumina, chrome, and iron; $R_2O_3, 2SiO_2$.

CHROMIUM. *Syn.* Chrome. Discovered by Vauquelin in 1797. It occurs as **CHROMIC IRON** in considerable quantity in the United States, on Cuba, &c.; as **CHROMATE OF LEAD**; and in smaller quantity in several other minerals. Although regarded 50 years ago as a substance possessing mere scientific interest and sparsely distributed over the earth, it is now largely employed in all the arts of coloring, from the beauty, brilliancy, and frequently the permanency of its combinations. *Sym.* Cr. *Equiv.* 28 (or 28.15). $H.=1$; 351.82 $O.=100$, *Berz.*)

I. CHROMIUM AND METALLOIDS.

Chromium. *Prop.* The green oxide is exposed to the violent heat of a blast furnace in a charcoal crucible. *Prop.* Porous, or in grains of a grayish white color between tin and steel; spec. grav. 5.9; very brittle, not magnetic; conducts electricity; scarcely attacked by cold nitric acid or aqua regia, but readily by fluoric acid; when heated in air, or kept under water, it slowly changes; in hot dilute sulphuric acid it evolves hydrogen, and decomposes steam when

heated in it; when heated with potassa, or soda, or their carbonates, or nitrates, it is converted into chromic acid.

Oxygen. 1. *Oxide of Chromium.* *Syn.* Green Oxide or Protoxide of C.; Chrome Green; *Ger.* Chromoxydul. Found native as **CHROMIC OCHRE.**

Prop. Technically it may be prepared from the crude materials formed by igniting chromic iron and saltpeter, but more readily and purer from the crystallized neutral or bichromate of potassa. *Tech.* 1. The mixed liquid, obtained by extracting the ignited ore and saltpeter, is concentrated in an iron vessel, and suffered to deposit in glass vessels; the clear liquor is then boiled with sulphur in the iron vessel, until oxide of chrome ceases to precipitate, filtered, the oxide dissolved in dilute sulphuric acid, precipitated by carbonate of soda, washed, and ignited. (*Frick.*) By dissolving it in muriatic, instead of sulphuric, evaporating, and igniting, the oxide has a finer color. (*Liebig.*) 2. Add to the mixed liquid above, a little sulphuric acid, filter, evaporate to dryness, ignite the residue with an equal amount of sulphur, and dissolve in water. (*Lassaigne.*) 3. Boil the mixed liquid and add to it a boiling solution of pentasulphuret of potassium, as long as the green oxide precipitates. (*Berzelius.*) From the yellow or red chromate of potassa it is obtained purer by 1, 2, and 3, but by 3 Wittstein ignites 19 pts. bichromate with 4 pts. sulphur for a half hour, and obtains $9\frac{1}{2}$ pts. of oxide. It may also be obtained, 4, by precipitating with a salt of mercury, washing, and igniting the chromate of mercury. 5. By igniting bichromate with about as much sal-ammoniac and a little carbonate of soda, until vapors of sal-ammoniac cease to rise, and extracting with water. 6. By adding sulphuric or muriatic acid, and then alcohol, to a strong solution of bichromate, precipitating the oxide by caustic or carbonated alkali, filtering, and igniting the hydrate or carbonate. 7. By adding sulphuric acid to a solution of chromate, passing sulphuretted hydrogen through it, filtering, and igniting. 8. By passing sulphurous acid through chromate in solution until it is fully green, precipitating by caustic or carbonated alkali, filtering, and igniting. 9. It may also be obtained crystallized by passing chromate of perchloride of chrome through an ignited glass tube, in which it deposits on the sides. (*Wöhler.*) 10. Dry chlorine is passed through a porcelain tube at a red heat, containing yellow chromate of potassa, which is decomposed into chloride of potassium and oxide of chrome; at a brown red heat the crystals are large green, friable laminæ; at a bright red, they are brown and hard. *Fremy.*

Prop. The crystals from 8 are mostly hemitrope, rhombs of the hexagonal system, greenish black, with metallic lustre, green powder, $H.=9$. The hydrate obtained by 6, 7, and 8, by caustic alkali and without ignition, is bluish green, in a thin layer transmitting red rays, loses its water by ignition, becoming the green oxide. *Form.* $Cr_2O_3 + 3HO$, containing 74.77 per cent. oxide. The ordinary oxide is of various shades of green, according to the mode of preparation.

Salts. They are readily formed by solution of the hydrated oxide or carbonate in acids, or by precipitation. The prevailing color of the salts is green, with red transmitted light, a few are bluish; the solutions are precipitable by caustic and carbonated alkaline bodies, a small amount being redissolved in excess of ammonia and its carbonate, if concentrated, and a large amount in excess of caustic potassa, but wholly precipitable again by boiling; they are precipitated, green by sulphhydrated alkali, light green by phosphate of soda, by iodide of potassium a whitish green; they are not precipitated by sulphuretted hydrogen, oxalic acid, or prussiate of potassa; the soluble salts are decomposed by ignition.

Analysis. The behavior of the salts just given indicate the presence of chrome, but the dry assay is more positive. It imparts an emerald-green color to the blowpipe fluxes, which is the same in the outer and inner flame, and distinguishes it from copper. Oxide of chromium may be separated by sulphuretted hydrogen from cadmium, lead, bismuth, copper, mercury, silver, gold, platinum, tin, antimony, and arsenic; and from nickel, cobalt, zinc, iron, and manganese, by adding tartaric acid to its solution, and then sulphhydrate of ammonia, which leaves chromium in solution; from alumina by caustic potassa and boiling; from magnesia by fusion with carbonated alkali; from the alkaline bodies by evaporating the sulphates to dryness and solution in alcohol. If chromic acid or the brown oxide be in solution, they may be reduced to green oxide (see *prep.* of green oxide, 3, 4, 6, 7, 8). Chromic acid is determined by precipitating with a solution of lead, barium, or mercury, weighing the 2 former, and igniting and weighing the latter. The green oxide is determined by precipitating the hot solution by ammonia, not concentrated.

Composition of green oxide:

	<i>Berzelius.</i>		
2 Cr.....	56	70	70.24
3 O.....	24	30	29.76
Cr ₂ O ₃	80	100	100

Cr₂O₃ = 1000.64, *Berz.*

Use. Oxide of chrome as an ordinary pigment is deficient in brilliancy, and apt to alter a little by time. Its most important application is as the rich green color on porcelain and fine pottery, it being one of the few colors that will resist the heat of a porcelain furnace, and therefore applicable under the glazing.

2. Brown Oxide of Chromium. Syn. Chromate of Chromium. Formed by digesting hydrated green oxide with chromic acid in slight excess, or by precipitating neutral chloride of chromium by neutral chromate of potassa. It is reddish brown while moist, black when dry, soluble in acids with a brown color, from which ammonia, if not in excess, reprecipitates it brown, but in excess forms chromate of ammonia and green oxide; it dissolves also in potassa. Form. CrO₂, or Cr₂O₃, CrO₃; the latter view that it is chromate of oxide of chromium is probably more correct.

3. Chromic acid. Ger. Chromsäure. Exists

in native chromate of lead, and is formed when oxide of chrome or chromic iron is heated with potash, saltpeter, or chlorate of potassa. *Prep.*

1. Distil 1 pt. fluor spar, 1 pt. chromate of lead, and 3 pts. fuming sulphuric acid in a lead retort, and transmit the gaseous fluoride of chromium into water contained in a vessel of lead, silver, or platinum; by mutual decomposition of the gas and the water, fluohydric and chromic acids are generated, the former of which is expelled by evaporating the solution to dryness; if the gas be conducted into a vessel only moistened with water, and its aperture closed by a piece of moist paper, the acid is obtained in the form of abundant acicular crystals of a cinnabar red color. 2. Decompose a hot concentrated solution of bichromate of potassa by silicofluohydric acid; the chromic acid, after being separated from the sparingly soluble silicofluoride of potassium, is evaporated to dryness in a platinum capsule, and then redissolved in a very small quantity of water. 3. Digest chromate of baryta or lead in an equivalent of dilute sulphuric acid, evaporate the dark ruby-red solution, and dry the irregular crystals on porous earthenware. 4. The best method consists in adding a concentrated hot solution of bichromate of potassa to an excess of oil of vitriol, pouring off the liquid from the red crystals, draining the latter in a funnel, drying them on porous brick, redissolving, and recrystallizing. The contact of paper and other organic matter must be avoided.

Prop. Black while warm, and of a rich carmine red color when cold; very soluble in water, rendering it red or yellow according to the degree of dilution; when the solution is concentrated by heat and allowed to cool, it deposits red crystals, which deliquesce readily in the air; also soluble in alcohol and ether, but the action of heat or light decomposes it; taste sour and styptic, and with alkalis it acts as a strong acid. It is converted into the green oxide, by exposure to a strong heat, by dry ammoniacal gas, and by most organic substances into green or brown oxide. It yields a chloride when heated with chlorohydric acid and alcohol, or in the direct solar rays; sulphurous acid changes it into sulphate of the oxide, 2 CrO₃ + 3 SO₂ = Cr₂O₃, 3 SO₃; the dry acid, heated with sulphuretted hydrogen, forms water, sulphur, and sulphuret of chromium, 2 CrO₃ + 6 HS = Cr₂S₃ + 6 HO + 3 S; the liquid acid forms water, sulphur, and oxide of chrome.

Composition:

	<i>Berzelius.</i>		
Cr.....	28	53.85	54.13
3 O.....	24	46.15	45.87
CrO ₃	52	100	100

CrO₃ = 651.82 (O = 100).

Chromates. The salts of chromic acid are basic, neutral, and acid; they are mostly either of a yellow or red color, usually brilliant. The chromates of most of the metals are decomposed by a strong red heat, the acid being resolved into green oxide and oxygen, but the chromates of the fixed alkalis sustain a very high temperature without decomposition; they

are all decomposed by the united agency of heat and combustible matter. The neutral chromates of protoxides are similar in constitution to the sulphates, their general formula being $\text{MO} = \text{CrO}_3$.

The chromates are often sufficiently distinguished by their color, but they may also be known by boiling them in chlorohydric acid mixed with alcohol, a green solution of the chloride of chromium being generated.

Use. Chromic acid developed by acids from bichromate of potassa, acts bleachingly on most organic colors by oxidation, and hence its use in calico-printing as a *discharger*. It is also an admirable oxidizer of organic bodies in the hands of the scientific chemist. Some of the metallic chromates (lead, &c.) are largely employed as pigments, and the alkaline chromates form the basis of brilliant and fast colors in dyeing and color-printing.

Sulphuret of Chromium. Formed by transmitting the vapor of bisulphuret of carbon over oxide of chromium at a white heat; by heating in close vessels an intimate mixture of sulphur and the hydrated oxide; by fusing the oxide with a pentasulphuret of potassium, and dissolving the soluble parts in water; or by transmitting sulphohydric gas aided by heat over the sesquichloride of chromium. It is dark-gray, acquires metallic lustre by friction, is readily oxidized when heated in the air, and is dissolved by nitric or nitro-muriatic acid. Form. Cr_2S_3 .

Phosphuret of Chr. Prepared by acting on the sesquichloride of chromium by phosphuretted hydrogen gas at a red heat, $\text{Cr}_2\text{Cl}_3 + \text{PH}_3 = \text{Cr}_2\text{P} + 3\text{HCl}$. It is black, insoluble in chlorohydric acid, feebly attacked by nitric and nitro-muriatic acid, and burns before the blow-pipe with a flame of phosphorus. Form. Cr_2P . Another phosphuret of a gray color is formed by exposing the phosphate of oxide of chromium to a strong heat in a charcoal crucible.

Nitroguret of Chr. Ger. Stickstoffchrom. Pass dry ammoniacal gas several times over dry and heated sesquichloride of chromium until sal-ammoniac ceases to form. It is a brown powder, burning with a red light in a stream of oxygen at 300° to 400° , evolving nitrogen and a little hyponitric acid, and leaving green oxide. Form. N_2Cr_3 .

II. HALOID SALTS.

Chlorine. 1. *Sesquichloride of Chromium.* *Prep.* 1. Transmit dry chlorine over a mixture of oxide of chromium and charcoal heated to redness in a porcelain tube, when the sesquichloride gradually collects as a crystalline sublimate of a peach-purple color. 2. Evaporate the green solution of this chloride gently to dryness at a temperature of 212° , when a green powder remains, consisting of 1 eq. of the sesquichloride and 3 eq. of water, $\text{Cr}_2\text{Cl}_3 + 3\text{HO}$. On raising the temperature above 212° , no water is lost until it reaches 400° : the powder then begins to swell up from the escape of water, the color changes from green to the red of peach-blossoms if the air be excluded. 3. By the action of chloride of sulphur on oxychloride of chromium.

Prop. There are two modifications of the

chloride, a soluble and insoluble. Both are peach-red, shining scales, transmitting the same color when thin, being opaque in thicker masses. The insoluble is attacked by the same reagents with more difficulty than the soluble. The chloride dissolves in water, forming a deep green solution with a sweet styptic taste. It may be prepared directly by dissolving the hydrated oxide in chlorohydric acid; or by digesting chromate of oxide of lead in strong chlorohydric acid, adding a little alcohol from time to time to promote the deoxidation of chromic acid, and then separating the resulting chloride of chromium from that of lead by strong alcohol, which, together with any excess of the acid, is ultimately expelled by evaporating to dryness. Traces of lead which may have been dissolved are easily precipitated by sulphohydric acid. Form. Cr_2Cl_3 , Eq. = 162.4.

2. *Oxychloride of Chr.* By evaporating, 1, to dryness, heating to 302° , and dissolving in cold water, a rose-red compound remains, with the formula, $2\text{Cr}_2\text{Cl}_3 + \text{Cr}_2\text{O}_3$; the solution evaporated over oil of vitriol leaves $2\text{Cr}_2\text{Cl}_3 + \text{Cr}_2\text{O}_3 + 9\text{HO}$. By heating above 302° nearly to ignition it forms $\text{Cr}_2\text{Cl}_3 + 2\text{Cr}_2\text{O}_3$; and by a continued ignition in the air it is wholly converted into the oxide.

3. *Chromate of Perchloride of Chr.* Syn. Chlorochromic acid. *Prep.* 1. Fuse together 10 pts. common salt and 16.9 pts. yellow chromate of potassa in a crucible, cast the fused mass, introduce the broken pieces into a large retort, together with 30 pts. fuming sulphuric acid; it passes over as a red gas while bisulphates remain, $3(\text{KO}, \text{CrO}_3) + 3\text{NaCl} + 12(\text{SO}_3, \text{HO}) = 3(\text{KO}, \text{HO}, 2\text{SO}_3) + 3(\text{NaO}, \text{SO}_3 + 3\text{HO}) + \text{CrCl}_3, 2\text{CrO}_3$. *Wöhler.* 2. Distil common salt, chrome yellow, and oil of vitriol, and redistil the distillate. *Dumas.*

Prop. A rich blood-red liquid; spec. grav. 1.71 at 70° ; boils at 244° ; spec. grav. of vapor = 5504; passed through an ignited glass tube it deposits crystallized oxide of chrome; it explodes with phosphorus, deflagrates with sulphur; it is also decomposed by ammonia, sulphuretted hydrogen, terchloride of phosphorus, mercury, alcohol, wood-spirit, turpentine and olive oils, camphor, olefant gas, and water; the action is usually violent; it dissolves iodine and chlorine. Form. $\text{CrCl}_3, 2\text{CrO}_3$, containing 43.66 per cent. chromic acid, or CrO_2Cl , with 35.27 per cent. chromium and 44.58 per cent. chlorine. According to the last formula, it is chromic acid, with 1 eq. chlorine substituted for 1 eq. oxygen, whence the name chlorochromic acid.

Sesquibromide of Chr. Formed by heating chromium and bromine, or by solution of the oxide in bromohydric acid; gray-green, deliquescent, sweet, styptic, easily decomposed by heat.

Fluorine. 1. *Sesquifluoride of Chr.* Formed by dissolving the oxide in fluohydric acid, and evaporating to dryness, when the sesquifluoride remains as a green crystalline residue, soluble in water, and combines with basic metallic fluorides to grass-green compounds. Form. Cr_2F_3 .

2. *Perfluoride of Chr.* A mixture of 3 pts. of

fluor spar and 4 of chromate of lead is distilled with 5 pts. of fuming or even common sulphuric acid in a leaden or silver retort; a red-colored gas is disengaged, which acts rapidly on glass, with deposition of chromic acid and formation of fluosilicic acid gas; is decomposed by water, and the solution contains a mixture of fluohydric and chromic acids. The watery vapor of the air effects its decomposition, so that red fumes appear from the separation of minute crystals of chromic acid. Formula, CrF_3 , or CrF_5 .

3. Chromofluorides of potassium, sodium, and ammonium are green powders, nearly insoluble in water.

4. *Silicofluoride of Chr.* Formed by dissolving the green oxide in silicofluoric acid; yields by evaporation a transparent, green, amorphous, deliquescent mass.

III. SALTS OF CHROMIC OXIDE.

1. *Sulphate of Chr. a. Neutral, crystallized.* By dissolving 8 pts. hydrated oxide of chromium in 9 pts. cold oil of vitriol, congeals in some weeks to a greenish blue crystalline mass, which forms a dark blue solution with water; (ruby-red by transmitted lamp-light;) and from this alcohol precipitates a pale violet crystalline powder. The powder is dissolved in a little water, as much more alcohol added, and suffered to evaporate in a vessel covered with a bladder. It forms regular 8-hedra of a deep violet color; spec. grav. 1.696; soluble in 0.833 water at 68° ; loses 9—10 eq. water at 212° , passing into *b*, and above the boiling point of linseed oil becomes *c*. The aqueous solution heated only to 149 — 158 passes into *b*. Form. $\text{Cr}_2\text{O}_3, 3\text{SO}_3 + 15\text{HO}$.

b. Neutral, amorphous. Formed like *a*, but with warm oil of vitriol, a green solution, not transmitting red rays by lamp-light, not crystallizable, nor precipitable by alcohol; by heat passes into *e*.

c. Neutral, insoluble. Formed by heating *a* or *b* until vapors of sulphuric acid begin to rise, and washing with water; in day-light it is pale red, in sun-light pale green; by lamp-light deeper green. Form. $\text{Cr}_2\text{O}_3, 3\text{SO}_3$.

d. $\frac{1}{3}$ basic. By saturating dilute sulphuric acid with hydrated oxide of chromium, a dark-green solution is obtained, which transmit red rays by sun and lamp-light. Formula, $\text{Cr}_2\text{O}_3, 2\text{SO}_3$.

e. $\frac{1}{3}$ basic. Formed by adding water largely to a concentrated solution of *d*; a light-green powder, losing its water by heat without fusion. Form. $3\text{Cr}_2\text{O}_3, 2\text{SO}_3 + 14\text{HO}$.

2. *Hyposulphate of Chr.* Small violet 8-hedra, soluble in water, with the form. $\text{Cr}_2\text{O}_3, \text{S}_2\text{O}_5$.

3. *Sulphite of Chr.* By solution of the hydrated oxide in aqueous sulphurous acid, a green solution is obtained, which, by boiling, lets fall a granular green basic salt.

4. *Sulphate of Chr. and Potassa. a. Crystallized.* Syn. Chrome-alum. 1. A mixed solution of sulphate of potassa and sulphate of chromium, (1. *a*), acidulated with sulphuric acid, is suffered to evaporate spontaneously. 2. Pass sulphurous acid as long as it is absorbed through a solution of 1 eq. bichromate of potassa and 1 eq. oil of vitriol. 3. Add 1 pt.

oil of vitriol, somewhat diluted, to 3 pts. of a saturated solution of yellow chromate of potassa, and when the solution is clear, add gradually 2 pts. alcohol. The crystals are regular 8-hedra, transparent, violet, and ruby-red, soluble in 6 pts. cold water, from which it crystallizes by spontaneous evaporation, easily decomposed by heat, whether solid or in solution. Formula, $\text{KO}, \text{SO}_3 + \text{Cr}_2\text{O}_3, 3\text{SO}_3 + 24\text{HO}$. (See ALUMS.)

b. By heating *a* to 392° it loses 22 eq. water, and to 572° , or more, it loses all its water, becoming anhydrous, forming in either case a green powder.

5. *Sulphate of Chr. and Soda.* Gradually mix 3 pts. sulphuric acid with 2 pts. bichromate of soda, and add alcohol. Not in distinct crystals, loses 16 eq. water at 212° , otherwise resembles 4, *a*, but is more efflorescent. Form. same as 4, *a*, with NaO for KO .

6. *Sulphate of Chr. and Ammonia.* Mix sulphate of ammonia with sulphate of chromium, 1, *a*. Regular 8-hedra, also combined with 6 and 12-hedra, violet, ruby-red by transmitted light, semi-transparent, efflorescent superficially, soluble in water to a violet-blue liquid, which is easily decomposed by heat, fuses to a green liquid without dichroism, losing 18 eq. water. Form. same as 4, *a*, with NH_3 , HO for KO .

Nitrate of Chr. Formed by solution of the hydrated oxide in nitric acid; is a green solution by reflected, a red by transmitted light; uncrystallizable, drying to a green gummy mass. By heat it becomes brown, and partly dissolves with a brown color, forming nitrate of brown oxide.

Bromate of Chr. Formed from bromate of baryta and sulphate of chromium, is a green solution, decomposed by evaporation, leaving nearly pure chromic acid.

Iodate of Chr. Formed from iodate of soda and chloride of chromium, is a light blue powder.

1. *Phosphate of Chr.* Formed by double decomposition, is a green precipitate, becoming bluish black by ignition. An acid salt is obtained by dissolving hydrated oxide in phosphoric acid; an emerald-green solution.

2. *Phosphite of Chr.* Precipitate a solution of sesquichloride of chr. by a solution of terchloride of phosphorus, neutralized by ammonia. A loose green powder, evolving pure hydrogen by ignition in a retort.

3. *Phosphate of Chr. and Soda.* Oxide of chr. dissolves in microcosmic salt, before the blowpipe, with a green color in the outer and inner flame, and with an excess of oxide exhibits an evolution of gas on cooling, in both flames, on platinum and charcoal.

1. *Borate of Chr.* Borate of ammonia gives light green, insoluble powder; borax a blue precipitate soluble in excess of borax; sexborate of potassa precipitates chrome-salts green.

2. Oxide of chrome dissolves slowly in borax in the inner blowpipe flame to a lively emerald-green glass, which is changed in the outer flame on platinum to yellowish brown.

Carbonate of Chr. Formed by double decomposition is a loose, light-greenish blue powder,

soluble in excess of alkaline carbonate. It is a mixed hydrate and carbonate.

IV. SALTS OF CHROMIC ACID.

The salts of chromic acid are procured from the neutral or bichromate of potassa of commerce, and the latter is made by igniting CHROMIC IRON ORE with potash in the air, or potash and saltpeter, &c.

The ore, freed, as well as possible, from its gangue, is reduced to a fine powder, by being ground in a mill under ponderous edge-wheels, and sifted. It is then mixed with one-third or one-half its weight of coarsely bruised nitre, and exposed to a powerful heat for several hours on a reverberatory hearth, where it is stirred about occasionally. The calcined matter is raked out, and lixiviated with water. The bright yellow solution is then evaporated briskly, and the chromate of potash falls down in the form of a granular salt, which is lifted out from time to time from the bottom with a large ladle, perforated with small holes, and thrown into a draining-box. This saline powder may be formed into regular crystals of neutral chromate of potash, by solution in water and slow evaporation; or it may be converted into the bichromate of potash, by treating its concentrated solution with muriatic or sulphuric acid. *Ure.*

The theory of the process consists mainly in the absorption of oxygen from the air by the contact of alkali, but the process is evidently defective, for after most careful ignition, a considerable quantity of oxide of chrome remains in the ore, and a portion still remains after several repeated ignitions. It is therefore evident that a new process is required, for the more complete transformation of the ore into chromate of potassa.

1. *Chromate of Potassa.* Syn. Yellow or Neutral Chromate of P. Ger. Einfach chromsaures Kali. *Prep.* 1. By recrystallization of the crude salt obtained by lixiviating the ignited ore and alkali. 2. By neutralizing cryst. bichromate, 2, by pure carbonate of potassa. 3. Introduce oxide of chrome into fused chlorate of potassa. The commercial yellow chromate is too often adulterated with sulphate, to attempt obtaining the pure salt from it economically.

Prop. Crystallizes in the right rhombic system, in oblique four-sided prisms, terminated by four-sided pyramids; two of the opposite lateral edges of the prism often replaced by planes; yellow, transparent; their coloring power is such that 1 pt. dissolved in 40,000 pts. water forms a yellow solution; it has an alkaline reaction, is permanent in the air; taste cooling, bitter, disagreeable; soluble in 2.07 pts. water at 60°; extremely soluble in boiling water, insoluble in alcohol.

Spec. grav. of solutions of the yellow chromate:

Salt	Water.	Spec. grav.
1	2	1.28
1	3	1.21
1	4	1.18
1	5	1.15
1	6	1.12
1	7	1.11
1	8	1.10

Spec. grav. of the saturated solution at 46½° = 1.368. Its spec. grav. is 2.6 to 2.7; may be heated to 400° without change; heated highly it assumes a crimson color, but recovers its yellow color on cooling; when fused at a red heat it becomes green, and crystallizes on cooling; decomposed by ignition with charcoal, sulphur, &c.; the aqueous solution is decomposed by sulphurous acid, alkaline sulphurets, arsenious acid, by heating with other acids and alcohol; parts with half of its base to other acids, and when the solution is concentrated, bichromate precipitates. Composition:

KO.....	47.2	47.58
CrO ₃	52.0	52.42
KO, CrO ₃	99.2	100

2. *Bichromate of Potassa.* Syn. Red Chromate of P. Ger. Zweifach chromsaures Kali. Obtained by adding sulphuric, muriatic, &c., acid to 1. Rectangular prisms, sometimes terminated by four-sided pyramids; color intense orange-red; not altered by exposure to the air; has an acid reaction; taste cooling, bitter, metallic; at 63° soluble in 9.6 pts. water; insoluble in alcohol; spec. grav. 1.9801; at a red heat it fuses into a transparent red liquid without farther loss than a little water mechanically held by the crystals, and crystallizes on cooling; at a white heat ½ the chromic acid loses ½ of its oxygen; 4 pts. oil of vitriol heated with 3 pts. bichromate, yields ½ its oxygen at a moderate heat; sulphurous and sulphohydric acids reduce the acid in solution to green oxide. Composition:

	H = 1.	In 100 pts.	Thomson.	Grouvelle.
KO.....	47.2	31.22	31.58	31.15
2 CrO ₃	104.0	68.78	68.42	68.85
KO, 2 CrO ₃	151.2	100	100	100

Uses. Both the yellow and red chromates of potassa are now largely employed in dyeing and dye-printing, the red much more extensively. The yellow and orange chromates of lead are securely fastened on fibrous textures, and Runge has shown that the bichromate is a powerful auxiliary in rendering some vegetable colors faster, and in varying their shade and hue. By using an acid (tartaric, &c.) the chromic acid is set free, and acts by its oxygen as a powerful topical bleaching agent.

3. *Chromate of Chloride of Potassium.* By boiling for a short time a solution of 2 with an excess of muriatic acid, the salt crystallizes out on cooling; KO, 2 CrO₃ + HCl = KCl, 2 CrO₃ + HO. Right rectangular prisms, orange red, transparent, permanent, decomposed by pure water, not by water acidulated by muriatic acid. Form. KCl, 2 CrO₃, containing 58.23 per cent. chromic acid.

1. *Chromate of Soda.* Formed similarly to the chromate of potassa, employing common soda instead of potash. Crystals oblique rhombic prisms, isomorphous with Glauber's salt; yellow, transparent. When heated, it melts in its water of crystallization; is very soluble in

water, sparingly in alcohol; deliquescent; evaporated above 86° the solution deposits the anhydrous salt. Form. $\text{NaO}, \text{CrO}_3 + 10 \text{HO}$, containing 30.02 per cent. chromic acid.

2. *Bichromate of Soda*. Hyacinth red; large 6-sided plates; more soluble in water than 1.

3. The chromate of chloride of sodium is deliquescent.

1. *Chromate of Ammonia*. Formed by evaporating chromic acid with ammonia in excess; crystalline scales, of a fine yellow color, a hot and saline taste, an alkaline reaction; very soluble in water; the salt is easily decomposed by heat into green oxide, sometimes with combustion. Form. $\text{NH}_3, \text{HO}, \text{CrO}_3$.

2. *Bichromate of Ammonia*. By concentrating the solution of the preceding, the bichromate is deposited in crystalline plates, of the oblique rhombic system, of a fine red color; taste hot and bitter; reddens litmus; is very soluble in water.

Chromate of Lithia. Yellow; crystallizes in oblique rhombic prisms; readily soluble in water.

Chromate of Baryta. Obtained by double decomposition, is a pale lemon-yellow powder, of inferior lustre; as insoluble in water as the sulphate; readily soluble with a reddish yellow color in muriatic or nitric acid as a bichromate. Form. BaO, CrO_3 .

Chromate of Strontia, formed like the preceding, is a fine yellow powder; tasteless; slightly soluble in water, not in alcohol; dissolves in nitric and muriatic acids.

Chromate of Lime, formed similarly, is yellow; slightly soluble. There appears to be an acid salt. Chromate of chloride of calcium is deliquescent.

Chromate of Magnesia, formed by solution of magnesia in chromic acid; large, transparent, yellow prisms, very soluble in water; of the same form as Epsom salt; spec. grav. at 59° 1.66. Form. $\text{MgO}, \text{CrO}_3 + 7 \text{HO}$. The chromate of chloride of magnesium is deliquescent.

Chromate of Yttria. By dissolving carbonate of yttria in chromic acid a brown basic salt separates, and the solution then yields yellowish brown, deliquescent needles of the neutral salt. Neutral chromate of *glucina* is yellow, insoluble; the acid salt uncrystallizable. The salt of *thorina* is a light yellow precipitate. *Alumina* forms a basic and acid salt, the latter with the formula, $\text{Al}_2\text{O}_3, 4 \text{CrO}_3$.

Chromate of Cerium. Formed by dissolving carbonate of cerium in chromic acid; deposits the yellow neutral salt, when the solution yields small red prisms of the acid salt.

Protochromate of Manganese. By mixing yellow chromate of potassa with a protosalt of manganese, a reddish brown crystalline precipitate is soon formed, composed, according to the formula, $2 \text{MnO}, \text{CrO}_3 + 2 \text{HO}$.

Perchromate of Iron formed by direct union, is a brown solution, which dries to a brown mass soluble in water and alcohol; formula, $\text{Fe}_2\text{O}_3, 4 \text{CrO}_3$.

1. *Chromate of Zinc*. If yellow chromate of potassa be added to a boiling solution of zinc vitriol, a basic salt precipitates, of a fine yellow color. The neutral salt is obtained in transparent, topaz-yellow crystals, in the form

of white vitriol, by dissolving carbonate of zinc in chromic acid; spec. grav. 2.096; very soluble in water; easily fusible. Form. $\text{ZnO}, \text{CrO}_3 + 7 \text{HO}$.

2. *Chr. of Zinc and Potassa*. Mix chromate of potassa and zinc vitriol, and let the mixture stand 24 hours; the yellow precipitate becomes orange-yellow from the formation of this double salt, which is slightly soluble in cold, more in boiling water, with a deep yellow color, and separation of a basic salt.

Chr. of Cobalt. Obtained with yellow chr. of potassa and a salt of cobalt, is light reddish brown, probably a basic salt. *Gmelin*.

Chr. of Nickel. A heated solution of chr. of potassa and sulphate of nickel gives a precipitate, probably basic. An acid salt is obtained by dissolving carbonate or hydrate of nickel in chromic acid; a red solution.

1. *Protochr. of Tin*. Add protochloride of tin to chromate of potassa in excess, with constant stirring; yellow caseous precipitate.

2. *Perchr. of Tin*, formed by double decomposition, is a yellow precipitate, becoming brownish yellow on drying, and violet by ignition.

1. *Chr. of Lead*. Syn. Chrome yellow. It occurs native and crystallized. It is manufactured: 1. By precipitating acetate or nitrate of lead by chromate or bichromate of potassa; usually by sugar of lead and the bichromate. 2. By carbonate of lead (white lead) and either chromate of potassa. (*Kuhlmann*.) 3. By cold digestion of still moist sulphate of lead with chromate of potassa. (*Liebig*.) The neutral sugar of lead and bichromate, especially in the cold, and not too concentrated, yield a more lemon-yellow pigment. It is not unusual to add sulphuric acid or a sulphate to the chromate, which gives a lighter yellow chromate and sulphate; some manufacturers add the chromate and a sulphate, simultaneously, but not previously mixed to the lead salt. The less neutral the lead salt is, the color of the pigment has more of an orange tint from the admixture of basic chromate of lead.

It is a lively yellow powder, insoluble in water, wholly soluble in potassa, the hot saturated solution of which deposits crystals of 2; it is also decomposed by carbonated alkali; decomposed by heating with sulphuric acid, with muriatic acid, forming chloride of chromium; becomes dark red by heat, and fuses by ignition to a dark brown mass; heated still higher it loses about 4 per cent. oxygen; by ignition in hydrogen or with charcoal, it is reduced to metallic lead and oxide of chromium. Composition:

	<i>Berzelius.</i>	
PbO	112	68.29
CrO ₃	52	31.71
PbO, CrO ₃	164	100
		100

2. *Basic Chr. of Lead*. Syn. Chrome-orange. 1. Boil the yellow chromate, 1, with dilute potassa, with white lead and water, with litharge and water, or with yellow chromate of potassa. 2. Mix a solution of litharge in caustic soda with chromate of potassa, and place the mixture under a bell glass, in which carbonic acid

CHROMIUM.

is slowly evolved by marble and sulphuric acid; it crystallizes in orange-yellow needles. (*Hayes*.) 3. Fuse saltpeter and neutral chromate of lead, and wash with water. (*Hayes*.) Throw chromate of lead gradually into fused saltpeter until nearly all the latter is decomposed, pour out the fluid mass, and wash the residue rapidly with water; it has a rich vermilion color. *Wöhler and Liebig*.

Color from orange to vermilion, usually crystalline, decomposed by acids. Composition:

			<i>Badams.</i>
2 PbO.....	224	81.16	80.98
CrO ₃	52	18.84	19.02
2 PbO, CrO ₃	276	100	100

Uses. Chrome yellow and orange are extensively employed as pigments, the former much more abundantly; they are characterized by great brilliancy and body. The red chromate is more liable to fade from atmospheric action. The yellow chromate mixed with Prussian blue forms a good green pigment, commonly called chrome-green.

Chr. of Bismuth, formed by double decomposition, has a rich yellow color.

Chr. of Uranium, obtained by solution of the carbonate in chromic acid, and slow evaporation. Brilliant red crystals, fusible with partial decomposition.

Chr. of Copper, formed by double decomposition with neutral chromate of potassa, is yellowish brown, probably basic, soluble in dilute nitric acid, and with a green color in ammonia. Strong alcohol precipitates from the latter solution a green double salt of chromate of ammonia and cupric oxide ammonia. Hydrate of cupric oxide dissolved in chromic acid, yields, by slow evaporation, transparent green crystals, of the form of blue vitriol, containing 33.5 per cent. water. (*Kopp*.) A basic salt of a rich green color is prepared by adding 2 pts. potash and 1 pt. chalk to a mixed solution of 48 pts. blue vitriol and 2 pts. bichromate of potassa, and pressing the precipitate. Another method consists in adding ammonia gradually to a solution of 2 pts. blue vitriol and 1 pt. bichromate, at the temp. of 68° to 86°, until the reddish brown precipitate becomes green. Unless prepared at the proper temperature it will not bear much washing.

1. *Mercurous chromate* is an orange yellow powder, most brilliant from a dilute solution, soluble in nitric acid, being resolved into 2. It leaves green oxide of chrome by ignition. Hg_2O, CrO_3 .

2. *Mercuric chromate* is a violet powder, soluble in acids, and partially in water, decomposable by an excess of alkali, and by ignition, a little of it subliming unaltered. HgO, CrO_3 .

1. *Chr. of Silver*. Formed by adding a soluble chromate to a solution of nitrate of silver, is a deep red precipitate, which has been considered as neutral chromate of silver. But if the precipitation be made with acid solutions a bichromate is formed. The latter salt is also obtained by the direct oxidation of metallic silver by a solution of bichromate of potassa

acidulated with sulphuric acid. The silver is oxidized at the expense of a part of the chromic acid; while another part, by uniting with the resulting oxide, forms the bichromate, which is deposited in tabular crystals of a rich crimson color. A chrome alum is at the same time formed, and the oxidation of this silver would appear to be induced by the affinity of the sulphuric acid for the oxide of chromium. On boiling the bichromate in distilled water, a part is dissolved and separated as the solution cools in beautiful micaceous crystals; but, at the same time, a portion of the salt is decomposed into chromic acid and neutral chromate of silver. As thus formed, the latter is of a dark green color: it is crimson, however, by transmitted light, and yields by trituration a powder similar in color to the precipitated chromate. *Warington in Turner's Chem.*

2. *Chr. of Silver and Ammonia*. Obtained by dissolving chromate, 1, in warm ammonia, forms yellow crystals of the same form as the corresponding salts of sulphuric and selenic acids; loses its ammonia by exposure. Form. $AgO, CrO_3 + 2NH_3$.

Chr. of Molybdenum. The neutral salt is a yellow solution, yielding yellowish scales or needles; the neutral is amorphous, soluble in water with a brown color; the basic, formed from either of the others by precipitation with ammonia, is a grayish yellow insoluble mass. Chromic and molybdic acids form a yellow, amorphous, soluble mass. *Chr. of Vanadium* is a brown, soluble mass. Chromate of potassa gives, with acid chloride of antimony, a brownish yellow precipitate.

CHROMYL. See XANTHOPHYLL.

CHRYSAMMIC ACID. *Prep.* One part aloes and 8 nitric acid, spec. grav. 1.37, are heated together, at first in an open vessel; and, when the first violent action is over, the whole is introduced into a retort, and distilled to two-thirds; about 4 pts. more acid are then added, and the mixture kept at a heat nearly boiling for some days, as long as gas is disengaged. The greater part of the acid being distilled off, water is added, which throws down impure chrysammic acid, while chrysolepic and oxalic acids remain in solution.

The precipitated acid is purified by washing with water, which removes nitric, chrysolepic, and aloetic acids. It then forms a greenish yellow crystalline powder, which still contains aloeresinic acid. It is now combined with potassa, and the salt purified by recrystallization. The pure salt is dissolved in water; and, on the addition of nitric acid, pure chrysammic acid is deposited.

Prop. A golden-yellow powder, composed of shining scales, soluble to some degree in hot water, forming a purple bitter solution; easily soluble in alcohol, ether, and hot acids; when heated it explodes; when heated in fuming nitric acid it is decomposed, yielding a new compound in golden scales, which forms with potassa an insoluble salt; with soda, one which crystallizes in needles of a greenish golden color. When heated with oil of vitriol, chrysammic acid yields dark gray adamantine crystals, which, when their solution is mixed with nitric acid, yield shining yellow scales, which

CHRYSANILIC ACID.

are not chrysammic acid. Formula of the chrysammic acid, $C_{15}H_9N_2O_{12} + HO$.

Chrysammate of potassa forms, when crystallized out of a saturated boiling solution, a carmine-red crystalline powder; and, when more slowly produced, small greenish golden crystals, like those of murexide. The salts of soda and magnesia are similar.

With ammonia chrysammic acid forms a deep purple solution, which deposits dark green crystals. These are not chrysammate of ammonia, but probably an amide. If their solution be mixed with nitric acid, it becomes of a brighter color, and on cooling deposits, not chrysammic acid, but black adamantine crystals, which, when boiled with potassa, yield ammonia and are reconverted into chrysammic acid. The other salts of this acid are of various shades of red, and all exhibit a golden lustre under the polishing steel. *Schunck in Turner's Chem.*

CHRYSANILIC ACID. See **INIGO**.

CHRYSEN, PYREN. *Chem.* Products of distillation of wood-tar. $\frac{4}{5}$ of the tar is distilled off, and the remaining $\frac{1}{5}$ distilled separately, and when crystalline scales of pyren appear, they are removed, stronger fire given, and the distillation continued until coal remains. The neck of the retort, cut off, is moistened with ether, the reddish matter scraped off, treated with ether, and washed with the same on a filter until it is pure yellow; the ether dissolves pyren, &c.

Chrysen. It is an inodorous and tasteless yellow powder, fusible at 446° — 455° ; sublimes, leaving a little coal; slightly soluble in ether and oil of turpentine, not in alcohol or water; becomes reddish brown with oil of vitriol, and dissolves with a dark green color; forms two compounds by treatment with nitric acid. Form. $C_{12}H_4$, or $C_{24}H_8$. *Binirite of chrysenes.* Formed by boiling chrysen with nitric acid, adding water, boiling it, and then boiling with alcohol. It is red, inodorous, and tasteless, slightly soluble in alcohol, ether, sulphuric acid, and tincture of potassa, the two last with a brown color, insoluble in water. Formula, $C_{24}H_6O_2 + 2NO_3$. *Binirite of chrysenis.* By boiling the preceding for a long time with nitric acid, it dissolves, and water precipitates from the solution an orange-red substance, of the formula, $C_{24}H_6O_3 + 2NO_3$.

Pyren. The ether employed in washing chrysen is mixed with the distillate, from which pyren separated, and cooled to 32° , the deposited pyren pressed in paper to remove oil, $\frac{4}{5}$ distilled, washed with a little ether, and crystallized from boiling alcohol. Microscopic, rhomboidal scales, of a faint yellowish color, fusible at 338° — 356° , wholly vaporizable, closely resembling paranaphthalin in appearance, and identical in composition, but behaving differently to nitric acid. Form. C_5H_2 . *Nitrite of Pyrenus.* Pyren is boiled with nitric acid, washed with water and boiling alcohol; orange-yellow, fusible in boiling alcohol, otherwise similar in behavior to the compounds of chrysen. Formula, $C_{15}H_5NO_4$. See *Distillation of Wood*.

CHRYSOBERYL. *Min.* Syn. Prismatic Corundum, *M.*; Cymophane, Alexandrite. *Descrip.*

CHRYSOLEPIC ACID.

Cryst. system, Right Rhombic, with vertical and horizontal prisms, and terminal planes, the 8-hedral faces being rare. $H. = 8.5$. $G. = 3.5$ — 3.8 ; 3.597, from Haddam, Connecticut; 3.733, from Brazil; 3.689, from the Ural, *Rose*. Color asparagus-green, grass-green, emerald-green, greenish white, and yellowish green; sometimes raspberry or Columbine red by transmitted light; transparent, translucent; lustre vitreous; streak white; it sometimes presents a bluish opalescence internally; fracture conchoidal, uneven.

Behavior. Unaltered alone, difficultly soluble in borax and mic. salt to a clear glass, cobalt solution colors it of a rich blue; perfectly decomposed by fusion with bisulphate of potassa.

Analysis. 1. From Brazil, by Thomson; 2, from Ural, by Awdejew.

	1.	2.
Alumina	76.75	78.92
Glucina	17.79	18.02
Protoxide of iron	4.49	3.12
	0.48	0.65
	99.51	100.71

The 0.48 in 1 was volatile matter, and the 0.65 of 2 was oxides of chrome, lead, and copper. Formula, GO, Al_2O_3 .

Local. Brazil; Ural; Haddam, Connecticut; Greenfield, near Saratoga, New York.

CHRYSOCOLLA. *Min.* Syn. Euchromatic Opaline-Allophane, *M.*; Copper-green. *Ger.* Kieselmalachite, Kieselkupfer. Botryoidal and massive. $H. = 2$ — 3 . $G. = 2$ — 2.238 . Color emerald and pistachio-green, passing into sky-blue; often brown when impure; translucent; opaque; lustre vitreous, shining, earthy; streak white; fracture conchoidal; rather sectile; translucent varieties brittle.

Behavior, &c. Yields water in a closed tube, and becomes black; gives the reactions of oxide of copper with borax and mic. salt, leaving a skeleton of silica in the latter; yields metallic copper with soda; soluble in acids, leaving silica. The probable form. is $3CuO, 2SiO_3 + 6HO$.

Local. It occurs with other ores of copper in Cornwall; Liebethen, Hungary; in Tyrol, Siberia; the Bannat, Thuringen; in the copper mines of New Jersey; at Morgantown, Pennsylvania; at Wolcottville, Connecticut, &c.

CHRYSOLEPIC ACID. Contained in the mother liquid and washings of chrysammic acid, and obtained by evaporation in crystals, which are purified by being combined with potassa, and recrystallization. The solution of the pure salt, treated with nitric acid, yields pure chrysolepic acid, in golden yellow scales, of a darker color than picric acid, which however it resembles in its properties. Formula, $C_{12}H_2N_3O_{13} + HO$, being the same as that of picric acid, from which it is distinguished by its salts.

Chrysolepate of potassa forms long shining yellow needles, which exhibit a violet metallic lustre by reflected light. *Chrys. of soda* forms long needles, which have a green metallic lustre. *Chrys. of silver* forms dark brownish red needles, which exhibit a play of red and green colors by reflected light.

CHRYSLITE.

A hot solution of the salt of potassa or soda gives with acetate of lead yellow brilliant crystals, which are composed of basic chrysolepate and acetate of lead. These crystals dissolve in acetic acid; and the solution, when evaporated, deposits dark-brown metallic-looking crystals, said to be neutral chrysolepate of potassa. These characters serve to recognise the chrysolepic acid, and to prove that it differs from picric acid. The acid itself, and its salts, explode when heated, like picric acid and the picrates. *Schwenk in Turner's Chem.*

CHRYSLITE. *Min.* Syn. Prismatic Chrysolite, *M. and J.*; Peridot, *H.*; Olivine, Chusite, Limbelite, Hyalosiderite. *Descrip.* Cryst. system, Right Rhombic, with vertical and horizontal prisms and terminal planes. Cleaves parallel with lateral terminal plane. Imperfect crystallizations: structure coarse or fine granular, aggregated in irregular spheroidal masses, imbedded in rocks. $H. = 6.5-7$. $G. = 3.33-3.5$; 3.441 of chrysolite, *Haidinger*; 3.3386-3.3445, (olivine), *Stromeyer*; 3.3514, (chrysolite), *Stromeyer*. Color green, of various shades, commonly olive-green; sometimes inclining to brown; transparent, translucent; streak white; lustre vitreous; fracture conchoidal.

Behavior, &c. Unalterable before the blow-pipe (Hyalosiderite darkens); with the fluxes shows the reaction of iron and silica, and gives a brown slag with soda. Easily decomposed by sulphuric acid, forming a jelly. Analysis of Meteoric olivine, see **AEROLITE**. Formula, $3 \text{MgO}, \text{SiO}_3$. In basaltic olivine FeO replaces magnesia, giving 10 eq. of silicate of magnesia to 1 eq. of silicate of iron; and in Hyalosiderite the ratio is 2 of the former to 1 of the latter, or $2 (3 \text{MgO}, \text{SiO}_3) + 3 \text{FeO}, \text{SiO}_3$.

Local. The perfectly crystallized chrysolite is brought from Constantinople: its locality is not known. Less distinct crystallizations occur imbedded in lava, at Vesuvius and the Isle of Bournon; imbedded in obsidian, at Real del Monte in Mexico; among sand at Expaillie in Auvergne, in pale green transparent crystals. Olivine is more abundant, being of frequent occurrence in basalt and lavas. Crystals, several inches in length, occur in greenstone at Unkel, on the Rhine; spheroidal masses are met with at Kapfenstein in Lower Styria; and at Hecla and Vesuvius. Olivine is common in the lavas and basalt of the Sandwich and other Pacific Islands. It is a frequent ingredient of meteoric stones.

CHRYSOPHANIC ACID. See **RHUBARB**.

CHRYSOPRASE. *Min.* See **QUARTZ**.

CHUSITE. *Min.* See **CHRYSLITE**.

CHYLE, CHYME. *Physiol.* See **DIGESTION**.

CICHORIUM. Syn. Wild Succory, Chicory, or Wild Endive. Extensively cultivated in Belgium, Holland, and Germany. The blanched leaves are sometimes employed at the table as a substitute for endive. The constituents of the leaves and root are extractive, chlorophyll, sugar, albumen, woody fibre, and salts. The root, when cut, dried, roasted, and ground (chicory coffee) is used as a substitute for, or to adulterate coffee. Chicory coffee yields a perfectly wholesome beverage, but which wants the fine flavor for which genuine coffee is so

CINCHONA.

renowned. It is extensively adulterated with roasted peas, beans, damaged grain, coffee husks, &c. Venetian red or Armenian bole is used for coloring. The medical properties of *Cichorium Intybus* are analogous to those of *Taraxacum Dens-leonis*. (*Perciva.*)

CICUTIN. See **CONICIN**.

CIDER. The fermented juice of apples. See the theory of **FERMENTATION**.

CIMOLITE. *Min.* A grayish clay, becoming reddish by exposure, found on the island Argenteira, (Cimola,) which appears to have the composition, $\text{Al}_2\text{O}_3, 3 \text{SiO}_3 + 3 \text{HO}$.

CINCHONA. Notwithstanding the great consumption of Peruvian bark in the preparation of Quinin and Cinchonin, we possess but few good analyses of the bark. It appears that there are numerous species, the bark of some yielding cinchonin, others quinin, and others again both alkaloids. The substances found in Peruvian bark are volatile oil, tannic acid, cinchona-red, quinic, and quinovic acids, quinin, cinchonin, aricin. Several other substances have been described, but too little is known with certainty to include them in the present work, such as chinoidin, quinova-bitter, blanquinin, &c. Chinoidin is said to be a mixture of quinin and cinchonin, and quinova-bitter is identical with smilacin. See **QUININ, &c., ARICIN and CINCHONIN**.

Volatile oil of Cinchona. Procured first by Fabbroni, afterwards by Trommsdorff. Obtained by submitting bark with water to distillation. The distilled water had the peculiar odor of the bark, and a bitterish acid taste. The oil which floated on the water was thick and butyraceous, and had the peculiar odor of the bark, and an acid taste.

Tannic acid. Soluble red coloring matter. This is a constituent of the most valuable kinds of cinchona. Its presence in an infusion of bark is detected by the ferruginous salts, by tartar emetic, and by gelatin: the first produces a green color or precipitate (tannate of iron), the second a whitish precipitate (tannate of antimony), the third also a whitish precipitate (tannate of gelatin). According to Pfaff, there is another principle in cinchona barks (resin, *Buchholz*), which forms a precipitate with tartar emetic; for the quantity of precipitate produced by this salt bears no ratio to that occasioned by the solution of gelatin; in some barks being more, in others less. Cinchona tannin is remarkable for the extreme facility with which its solution absorbs oxygen, and becomes colored when exposed to the air, especially under the influence of alkalies. The red insoluble matter which is formed is, according to Berzelius, cinchona red. The combinations of cinchona tannin with acids are more soluble than those of gutgall tannin.

Cinchona red. Insoluble red coloring matter. This substance is considered by Berzelius to be a product of tannin altered by the air, and to consist of tannin and apothème. It is inodorous, insipid, and of a reddish-brown color; insoluble, or nearly so, in cold water, but somewhat more soluble in boiling water; acids favor its solution in water; soluble in alcohol (especially when hot), but scarcely so in ether; its aqueous solution has not, either with or

CINCHONIN.

without an acid, the power of forming a precipitate with a solution of gelatin, but it has with emetic tartar. If, however, cinchona red be dissolved in an alkaline solution, and then precipitated by an acid, it acquires the power of precipitating gelatin; but if heated with a solution of potassa or soda, it loses this power. *Pereira.*

CINCHONIN. *Prep.* For the general method of obtaining the organic alkalies, see **ALKALOID**. It is separated from quinin by its different solubility, and may be obtained from a hot saturated, alcoholic solution in oblique 4-sided prisms, or in fine needles; is anhydrous, colorless, inodorous, and bitter. When heated this salt does not fuse until it begins to decompose: it then fuses, furnishes a crystalline sublimate (cinchonin?) gives out ammonia, and leaves a carbonaceous residuum. It is almost insoluble in cold, soluble in 2500 pts. of hot water; the hot solution becomes opaque as it cools; soluble in alcohol, especially when hot, but less than that of quinin in this fluid; soluble in ether, but much less so than in alcohol; it dissolves slightly in fixed oils, somewhat more so in oil of turpentine, and readily in diluted acids.

Form. $C_{20}H_{12}NO$. Sym. Cin.

Salts. The salts of cinchonin are neutral and basic, the former having usually an acid reaction, crystallizable, bitter; generally more soluble in alcohol and water than the corresponding salts of quinin, nearly insoluble in ether; their aqueous solutions are precipitated white by caustic and carbonated alkali, oxalic, tartaric, and tannic acids and their salts, yellow by gold and platinum solutions; they are colored brown by iodine, green by permanganate of potassa; they are distinguished from salts of quinin, by the precipitate with alkali not softening like resin when the liquid is warmed, and not dissolving in ether, and by their solutions not clouding with nitrate of silver or of red oxide mercury.

Basic Muriate of Cinchonin. Transparent, shining, oblique 4-sided prisms, with 3 or 4 end-planes, or branching needles, fusible below 212° , very soluble in alcohol and water, scarcely in ether, precipitable by chloride of mercury. Form. 2 Cin, HCl . The double salt with bichloride of platinum is yellow, crystalline, soluble in 500 pts. boiling water. Form. $\text{Cin, HCl} + \text{PtCl}_2$.

Basic Iodohydrate of Cin. Transparent, pearly needles, difficultly soluble in water. Formula, $2\text{ Cin, HI} + 2\text{ HO}$.

1. *Neutral Sulphate of Cin.* Rhombic octahedra, slightly efflorescent; soluble at 57° in 0.46 pts. water, 0.9 pts. alcohol (of 0.85), and 1 pt. absolute alcohol, insoluble in ether. Form. $\text{Cin, SO}_3 + 4\text{ HO}$. 2. *Basic.* Syn. Disulphate of Cinchonin, Subsulphate of Cinchonin. Its crystals are short, oblique prisms, terminated by dihedral summits; taste bitter; when heated to 212° it becomes phosphorescent, and above 212° fuses; at 248° loses 2 eq. water of crystallization; soluble in 6 pts. of alcohol of 0.85, and in 11 pts. of absolute alcohol; in 54 pts. of cold water. Form. $2\text{ Cin, SO}_3 + 3\text{ HO}$. 3. *Hyposulphate of Cin.* is crystallizable.

The *phosphate* and *arsenate* are very soluble,

CINNAMON.

difficult to crystallize. The *nitrate*, at first amorphous, becomes crystallized in rectangular prism, very soluble. Form. $2\text{ Cin, NO}_5 + 3\text{ HO}$. The *chlorate* forms fine, shining needles, explosive by heat. The *iodate* forms fine, silky needles, soluble in alcohol and water, exploding at 248° .

Oxalate of Cin. is a white powder, slightly soluble in water, readily in alcohol and free oxalic acid. The *tartrate* is white, nearly insoluble in water. The *acetate* is either neutral, and difficultly soluble, or acid. The *tannate* is yellowish white, somewhat soluble in hot water, from which it separates in crystalline grains. *Quinate of Cin.* is granular, or in silky needles, soluble at 59° in 0.5 pts. water, less in alcohol; from the boiling saturated tincture a basic salt separates and an acid salt remains in solution; it contains 4 eq. water.

CINNABAR. *Min.* Syn. Peritinous Ruby Blende, *M.*; Sulphuret of Mercury. *Ger.* Zinnober, Quecksilber-Lebererz, *W.*; Stinkzinnober Lebererz, *Haus.* *Kwaßaggr.* *Theoph.* c. 103; *Amicus, Dioscor.* v. c. 109, 110; *Minium. Vitruv. Plin.* *Descrip.* Cryst. system, Hexagonal, consisting of combinations of rhombs with a 6-sided prism and terminal plane; cleaves parallel with the prism. Imperfect crystallizations: granularly massive, particles usually small, and often impalpable; sometimes forming superficial coatings. $H. = 2-2.5$. $G. = 8.098$, a cleavable variety from Neurmarktel. Color cochineal-red, the darker varieties inclining to brownish red, and lead-gray; subtransparent, subtranslucent; lustre adamantine, inclining to metallic in dark-colored varieties, and to dull in friable varieties; streak scarlet-red; fracture subconchoidal, uneven; sectile.

Behavior, &c. Volatile on charcoal with sulphurous odor; sublimes unchanged in a closed tube; in an open tube it sublimes both as mercury and cinnabar, and wholly as mercury, if mixed with soda; the impure varieties leave the earths or oxides by sublimation. Formula, HgS .

Local., &c. The hepatic cinnabar or liver ore is an impure variety of this species; it sometimes affords a brownish streak, is occasionally slaty, though commonly granular or impalpable. Cinnabar is usually associated in beds with native mercury, native amalgam, and occasionally only with calcareous spar and quartz. It has been observed in veins, with ores of iron. The finest crystals occur in the coal formations of Moschellandsberg and Wolfstein, in the Palatinate; also in Japan, Mexico, and Brazil. The most important beds of this ore are at Almaden in Spain, and at Idria in Carniola, where it is usually massive. It occurs at Richenau, in Upper Carinthia, in beds traversing gneiss; at Dunbrawa, in Transylvania, in graywacke; at Windisch Kappel, in Carinthia; at Neurmarktel, in Carniola; in Chili, South America, &c. The variety *Coralinerz*, from Idria, has a curved lamellar structure. This ore is the great source of the mercury of commerce, from which it is obtained by sublimation. *Dana.*

CINNAMON-STONE. *Min.* See **GARNET**.

CINNAMON. The bark of the *Cinnamomum*

Zeylanicum and *Cin. Cassia* yield analogous essential oils by distillation with water. The oil is supposed to contain a radical *Cinnamyl*, the hydruret of which is the oil and its oxide cinnamic acid. Formula of cinnamyl, $C_{18}H_{17}O_2$. Sym. Cnm. *Dumas and Peligot*.

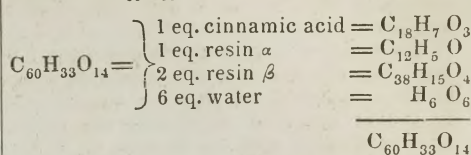
Oil of Cinnamon. It is a yellow oil, heavier than water, possessing the odor of cinnamon, solid below 32° , melting at 23° ; has a pungent, burning, sweetish taste; deposits crystals when kept, and when exposed to the air becomes brown, and passes into cinnamic acid; sparingly soluble in water, forming cinnamon water. This solution, mixed with iodine and iodide of potassium, yields brilliant reddish-brown crystals of a strong metallic lustre; the probable composition of which, according to Apjohn, is $KI + I_3.CiH = KI + (C_{18}H_{17}O_2 + H) + I_3$. They are soluble in ether and alcohol without alteration, but are decomposed by water. *Apjohn*.

Aqua potassæ dissolves oil of cinnamon easily and completely, and diluted acids separate it again unchanged from the solution. If the solution of the oil in potassa be distilled, an oil passes over with the vapor of water, which is lighter than water, has an odor of cinnamon and bitter almonds, and is composed according to the formula, $C_{18}H_{10}O_2$; the residue contains benzoate of potassa, mixed with a black matter. (*Mulder*.) Oil of cinnamon, heated with hydrate of potassa, gives off hydrogen gas. The oil, if mixed with nitric acid in the cold, becomes thick, and is wholly or partially converted into a crystalline mass. If boiled with nitric acid, the smell of oil of bitter almonds is perceived, and benzoic acid is found in the residue. Benzoic acid is also formed by the action of hypochlorites on the oil of cinnamon. Ammoniacal gas solidifies the oil, producing undoubtedly several bodies; one of which is soluble in alcohol and ether, and crystallizes in fine silky needles grouped together. With hydrochloric acid it forms a green solid mass, composed of an equal number of equivalents of the anhydrous oil and of hydrochloric acid. Chlorine decomposes the oil of cinnamon, forming a liquid compound, and another which sublimes in long white needles. The latter has the formula $C_{18}H_4Cl_4O_2$; and consequently it is oil of cinnamon in which half the hydrogen has been replaced by its equivalent of chlorine. It is termed chlorocinnose.

According to Blanchet and Sell, the oil of cinnamon consists of two distinct oils, one heavier, and one lighter than water. The heavier has at 77° a spec. grav. of 1.008, and boils at 430° . If the commercial oil be treated with barytic water, a saline combination of the heavy oil is produced, which is soluble in water, and from which the heavy oil is separated by acids. The lighter oil may be distilled from the mixture of the commercial oil with baryta.

According to Mulder, the oils of cinnamon and cassia have the formula $C_{20}H_{11}O_2$, when quite fresh. On exposure to the air, they rapidly absorb oxygen; and produce cinnamic acid, two resins, and water. Mulder has analyzed both the resins, which he calls resin α and resin β . The former is soluble in cold

alcohol, and its formula is $C_{15}H_{11}O_2$. The latter is insoluble in cold alcohol, and has the formula $C_{12}H_5O$. If we compare the composition of these resins and of cinnamic acid with that of the oil, we find that 3 eq. of oil of cinnamon = $C_{60}H_{33}O_6 + 8$ eq. oxygen =



The 8 equivs. of oxygen are derived from the air. Oil of cinnamon is decomposed by hydrochloric acid gas, yielding a volatile oil not yet examined, water, and two resins, one soluble, the other insoluble, in cold alcohol. The formula of the latter is $C_{20}H_8O$; that of the former $C_{14}H_5O$. In like manner, concentrated sulphuric acid acts on the oil, producing two resins, one soluble, the other insoluble, in alcohol. The composition of the

former is..... $C_{30}H_{15}O_2$, or
that of the latter..... $C_{30}H_{15}O$

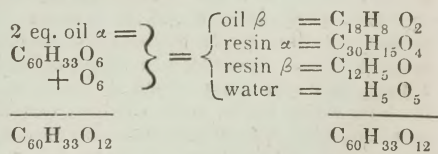
Together..... $C_{60}H_{30}O_3$, which is

3 at. oil of cinnamon — 3 at. water. The sulphuric acid removes an atom of water from each atom of the oil, and the oxygen of the residue is unequally divided between the resins.

With nitric acid, oil of cinnamon forms a white crystalline compound, $C_{18}H_9NO_7$. The oil $C_{20}H_{11}O_2$ loses here C_2H_2 , and takes up NO_5 , and the rational formula of the resulting compound is probably $C_{18}H_8O_3 + NO_3 + HO$; which explains its decomposition by contact with water, and the formation of cinnamic acid when it is dissolved in sulphuric acid. With water it yields an oil which is $C_{18}H_8O_2$, that is, hyduret of cinnamyl; while its solution in sulphuric acid, when mixed with water, deposits cinnamic acid, $C_{18}H_7O_3$.

Along with the crystalline compound, nitric acid produces a red oil, which is instantly decomposed by water, although not by anhydrous alcohol or ether. With water the red oil yields another oil, the formula of which is $C_{15}H_7O_2$. *Mulder in Liebig's Turner*.

Kane's view is that the oil of cinnamon (oil α) $C_{20}H_{11}O_2$ absorbs O_6 from the air, and becomes oil β together with the two resins α and β , as thus shown:



Cinnamic acid. It is formed in hard translucent prisms, when oil of cinnamon is long exposed to the atmosphere. It may also be obtained by dissolving in potassa the oil of Peru balsam with a gentle heat, evaporating to dryness, dissolving the residue of cinnamate of potassa in boiling water, and adding an excess of hydrochloric acid; the cinnamic acid

crystallizes on cooling, and is purified by repeated crystallization. Colorless, transparent scales, having a weak aromatic taste; less soluble in hot and cold water than benzoic acid. It crystallizes from alcohol in colorless rhombic prisms, which are hard and friable, fusible at 240° , boiling at 555° , and distilling as a heavy oil, which consolidates on the neck of the retort to a white crystalline mass. By the action of nitric acid it is converted into oil of bitter almonds, and then into benzoic acid; by farther action of nitric acid, nitricinnolic acid is formed, with the formula $C_{14}H_5NO_8$; cinnamic acid seems to form with sulphuric acid, chlorine, bromine, and iodine of peculiar acids; distilled with lime, cinnamic acid yields cinnamole. The formula of anhydrous cinnamic acid is $C_{18}H_7O_3$. Sym. CiO . The salts of cinnamic acid are analogous to the benzoates. The alkaline are soluble, with the formula, $KO (NaO, NH_3) CiO + HO$; those of the alkaline earths are difficultly soluble, crystalline, $BaO (SrO, CaO) CiO + 2 HO$; the salt of manganese gold-yellow crystals, the salts of iron pale yellow, insoluble, those of lead and silver, white, the former sparingly soluble, $AgO, (PbO) CiO$.

Cinnamic Ether. Formed by distillation of 4 pts. absolute alcohol, 2 pts. cinnamic, and 1 pt. muriatic acid, shaking with water and rectifying over litharge. Plantamour obtained it by distilling a concentrated tincture of potassa with cinnamein. A clear liquid of spec. grav. 1.13, boiling at 500° . Form. $C_4H_{50} + C_{18}H_7O_3$, or AeO, CiO .

Cinnamole. Syn. Cinnamomin, Cinnamen. Obtained by the dry distillation of 1 pt. cinnamic acid with 3 pts. caustic lime or 4 pts. baryta. It is a light, colorless, iridescent liquid with an odor and taste both of bitter almond oil and naphtha; spec. grav. = 0.88, boils at 192° (at 284° , *Gerh.* and *Cah.*); spec. grav. of vapor 3570; insoluble in water, soluble in alcohol and ether; forms a white body with sulphuric acid, sulphocinnamid, and crystallized compounds with chlorine and bromine. Form. of cinnamole, $C_{16}H_8$.

Cinnamein and Peruvine. The balsams of Peru and Tolu contain compounds which belong to the series of Cinnamyl.

Cinnamein. According to Stoltz and Wernher, 2 vols. of balsam of Peru, and 3 vols. of aqua potassæ, spec. grav. 1.300, when heated together, produce a yellow or yellowish-brown oil, (oil of Peru balsam,) which swims above a dark brown or black syrupy liquid, soluble in water, which contains all the potassa. The former is purified by distillation; it is then clear and colorless. According to Plantamour and Fremy, this substance which is allied to the fat oils, when boiled with alkalis, produces cinnamic acid, which combines with the alkali, and a neutral substance, peruvine, just as in

the same saponification of fat oils. When cinnamein is exposed to a cold of $+ 26^{\circ}$, it deposits neutral crystals, soluble in alcohol and ether, the formula of which is $C_{18}H_8O_3$, exactly that of hydruret of cinnamyl. This substance, therefore, is isomeric with hydruret of cinnamyl, as benzoin is with hydruret of benzyl.

Cinnamein, mixed with oil of vitriol, is converted into a brown, resinous matter, which appears to be a compound of 1 eq. cinnamein and 7 eq. water. By the action of chlorine, cinnamein is converted into chloride of benzyl, and an oily fluid, containing no chlorine, which cannot be separated from it. Formula of cinnamein, $C_{54}H_{26}O_8$.

Peruvine is a colorless oily fluid, lighter than water, refracting light powerfully; its composition approaches to $C_{36}H_{25}O_4$. According to this formula, 1 eq. cinnamein produces 3 eq. cinnamic acid, and 1 eq. peruvine. *Liebig's Turner.*

CITRIC ACID. Discovered by Scheele in 1784. It exists ready formed, both free and combined, in the juice of most ordinary fruits, lemon, orange, currant, &c., and in the sap of many other plants.

Prep. 1. Neutralize lime juice with chalk, dilute it with water to a paste, add gradually, while stirring, as much oil of vitriol as chalk employed, previously diluted with 5 pts. water, warm the mixture to complete the decomposition, draw off the clear settled liquid, and evaporate at first in lead vessels over the naked fire, then in a water-bath, to crystallization; by resolution, bone-black, and recrystallization it may be purified. 2. Let the juice of currants ferment, distil off the alcohol, and treat the remainder as in 1. 100 pts. currants yield 10 pts. alcohol, of 10° Beaumé, and 1 pt. citric acid.

Prop. Regular, rhombic prisms, with 8-hedral terminations, colorless, of intense acid and agreeable taste, soluble in 1 pt. water to a syrupy liquid, crystallizing from a cold saturated solution with 5 eq. water; these crystals lose 9.4 per cent. (2 eq.) water at 212° ; crystallizing from a solution saturated at 212° with 4 eq. water, which loses nothing at 212° . A solution of the acid reduces chloride of gold without effervescence; warmed with binoxide of manganese it evolves carbonic and acetic acids; 1 pt. cryst. acid, warmed with 4 pts. oil of vitriol, evolves carbonic oxide (acid also?), and by a higher heat acetic acid, thus 1 eq. citric acid = $C_{12}H_5O_{14} = 2 CO_2 + 2 CO + 2 (C_4H_3O_3, HO)$. By fusion with an excess of potassa it is resolved into oxalic and acetic acids; $C_{12}H_5O_{14} + 2 HO = 2 (C_4H_3O_3, HO) + 2 (C_2O_3, HO)$.

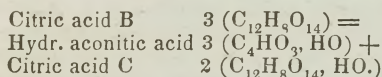
Tests. It is wholly soluble in alcohol; a few drops added to lime-water, remains clear until heated, and the then precipitate is soluble in acids without effervescence.

Formula.

- A. Anhydrous acid = $C_{12}H_5O_{11} = \bar{Ci}$,
- B. D heated to $212^{\circ} = C_{12}H_5O_{11} + 3 HO = \bar{Ci}, 3 HO$,
- C. Cryst. from $212^{\circ} = C_{12}H_5O_{11} + 4 HO = \bar{Ci}, 3 HO, aq.$
- D. Cryst. cold = $C_{12}H_5O_{11} + 5 HO = \bar{Ci}, 3 HO, 2 aq.$

Berzelius adopts for anhydrous citric acid the formula $C_4H_2O_4$, or $C_6H_3O_6$.

Citrates. Citric acid forms with bases neutral and basic salts. The formula of the neutral tribasic salts is $\overline{\text{Ci}} + 3 \text{MO} + \text{aq.}$, and they correspond to the acid C, its basic water being replaced by an eq. of protoxide. They contain, besides, 1 eq. of crystal-water, which they lose when heated, when their formula is $\overline{\text{Ci}} + 3 \text{MO}$, corresponding to the acid B. In the basic salts, either the crystal-water of the neutral salts is replaced by an eq. of protoxide, $\overline{\text{Ci}} + 3 \text{MO} + \text{MO}$, being thus also analogous to C; or else, in addition to this, they contain 1 eq. crystal-water, $\overline{\text{Ci}} + 3 \text{MO} + \frac{\text{MO}}{\text{HO}}$, corresponding to the acid D. The only bibasic citrate yet examined is that of lead, in which 2 of the 3 at. of basic water of the acid D are replaced by oxide of lead. The citrates, when heated, froth, blacken, and give off an acid liquid. When an anhydrous citrate, $\overline{\text{Ci}} + 3 \text{MO}$, is decomposed by an alcoholic solution of hydrochloric acid, so that each eq. of citric acid can only obtain 3 eq. water, formed by the oxygen of the oxide, and the hydrogen of the hydrochloric acid, the citric acid resolves itself into hydrated aconitic acid, and the citric acid C; thus,



Cit. of Potassa. Three citrates of potassa exist, $\overline{\text{Ci}}, 3 \text{KO}$; $\overline{\text{Ci}}, 2 \text{CO}, \text{HO}$; and $\overline{\text{Ci}}, \text{KO}, 2 \text{HO}$; they are soluble and crystallizable.

Cit. of Soda. Formula of the tribasic salt, $\overline{\text{Ci}}, 3 \text{NaO}, 11 \text{aq.}$ *Berz.* It forms large regular crystals; at 212° they lose 7 eq. water, leaving $\overline{\text{Ci}}, 3 \text{NaO}, 4 \text{aq.}$, and when heated to from 360° to 380° , the remaining 4 eq. water are expelled; but a portion of the salt is converted into aconitate of soda. It is insoluble in alcohol. The bibasic salt, $\overline{\text{Ci}}, 2 \text{NaO}, \text{HO}$, obtained by adding to a solution of the last salt half as much citric acid as it already contains; forms by spontaneous evaporation small prismatic crystals. The monobasic salt, $\overline{\text{Ci}}, \text{NaO}, 2 \text{HO}$, obtained by a similar process, adding a quantity of citric acid equal to that already present; forms a gummy amorphous mass, but may be obtained in crystalline grains from an alcoholic solution.

Cit. of Baryta. Citrate of soda added to chloride of barium causes a white precipitate, $\overline{\text{Ci}}, 3 \text{BaO}, 7 \text{aq.}$ *Berz.* A heat of 300° expels 6 eq.) a higher temperature the last eq. of water. When a hot solution of citric acid and chloride of barium is added to a hot solution of citrate of soda till the precipitate is dissolved, and the mixture allowed to cool, a crystalline powder is deposited, which contains $2 \overline{\text{Ci}}, 5 \text{BaO}, \text{HO} + 7 \text{aq.}$, and must be viewed as a compound of the salt first described with a bibasic salt, $\overline{\text{Ci}}, 2 \text{BaO}, \text{HO}$.

Citr. Lime. The tribasic salt, formed like that of baryta, is $\overline{\text{Ci}}, 3 \text{CaO}, 4 \text{aq.}$ *Berz.* The precipitate formed by heating citric acid with an excess of lime-water is a basic salt, $\overline{\text{Ci}}, 3 \text{CaO}, + \text{CaO}, \text{HO}$; at 212° it is converted into

$\overline{\text{Ci}}, 3 \text{CaO}, \text{CaO}$. The salt formed by adding chalk to lime juice, from which citric acid is obtained, is a mixture of the two salts just described.

Magnesia, alumina, and protoxide of manganese, each form with citric acid an insoluble tribasic and a soluble acid-testing salt. The citrate of protoxide of iron, formed by digesting iron-filings with a concentrated solution of citric acid at 158° to 176° , separates as white crystals. The salt of the peroxide is brown and soluble. The double alkaline percitrate of iron are now highly esteemed as chalybeates. Citrate of zinc is sparingly soluble.

Citr. of Lead. The tribasic salt, $\overline{\text{Ci}}, 3 \text{PbO}$, aq. is a white powder, resolved, by washing with water, into the soluble bibasic salt, and an insoluble salt with excess of base. The bibasic salt, $\overline{\text{Ci}}, 2 \text{PbO}, \text{HO}, + 2 \text{aq.}$ forms crystalline grains. The basic citrate occurs in two forms; the first is $\overline{\text{Ci}}, 6 \text{PbO}$: the second, $\overline{\text{Ci}}, 3 \text{PbO}, \text{PbO}, \text{HO}$.

The only citrate of copper yet described is a green crystalline powder, $\overline{\text{Ci}}, 3 \text{CuO}, \text{CuO} = \overline{\text{Ci}}, 4 \text{CuO}$; which becomes blue by heat; it contains, therefore, an excess of base.

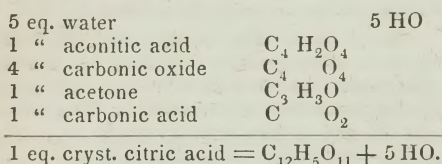
Citr. of Silver forms a brilliant white powder, which, if washed and dried below 60° , is $\overline{\text{Ci}}, 3 \text{AgO}, \text{aq.}$; when heated to 70° it gives off water, and becomes $\overline{\text{Ci}}, 3 \text{AgO}$.

Potassa-citrate of Antimony has properties analogous to tartar emetic, forming dazzling white prisms; it is composed of $\overline{\text{Ci}}, \text{Sb}_2\text{O}_3 + \overline{\text{Ci}}, 3 \text{KO} + 5 \text{aq.}$, *Thaulow*; the water is expelled at 375° .

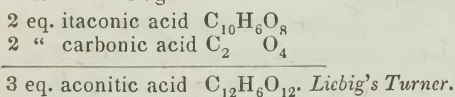
Citr. of Oxide of Ethyl. Syn. Citric ether. Obtained by heating a mixture of citric acid, alcohol, and oil of vitriol, till ether begins to distil over, and mixing the residue in the retort with water, when the citric ether separates as a heavy oily fluid, which is washed with water, dissolved in alcohol, decolorized by charcoal, and the alcohol dissipated by heat. It has a faint smell of olive oil, and a bitter taste; spec. grav. = 1.142; boils at 540° , but is partially decomposed, yielding carbon, pyrocitric acid, and alcohol; converted by alkalies into citric acid and alcohol; but not altered by acids in the cold, nor by chlorine and bromine.

Action of heat on Citric acid. Investigated by Lassaigne, Dumas, Baup, Robiquet, Dahlström, and Berzelius, and recently with success by Crasso. According to Crasso, crystallized citric acid, when exposed to heat, exhibits four stages of decomposition. During the first the crystal-water alone is given off, and the residue contains unaltered citric acid. The second stage is characterized by white vapors, and the production of acetone, carbonic oxide, and carbonic acid, while the residue consists of hydrated aconitic or pyrocitric acid. In the third stage, the aconitic acid, not being volatile, is itself decomposed, yielding carbonic acid, and an oily liquid, which soon crystallizes, and is itaconic or pyroaconitic acid, the citric acid of Baup. In the fourth stage empyreumatic oil is produced, and a voluminous coal remains behind. He has further shown that the aconitic

acid, heated by itself, is converted into itaconic acid and carbonic acid; and that the itaconic acid, when heated, yields a volatile acid isomeric with itself, citraconic acid, which is identical with the citribic acid of Baup, and which is always more or less formed along with the itaconic acid, owing to the easy decomposition of the latter. The action of heat on citric acid, therefore, gives rise to three distinct acids in regular sequence; 1st, aconitic or pyrocitric acid; 2d, itaconic or pyroaconitic acid; 3d, citraconic or pyro-itaconic acid. The changes by formula are for the 1st stage:



For the 2d stage:



See ACONITIC, ITACONIC acid, and the following article.

CITRACONIC ACID. *Chem. Syn.* Pyro-itaconic, Citribic acid. Obtained by distilling aconitic or itaconic acid, the last portions of the distillate being anhydrous oily citraconic acid, the 1st portions the same mixed with water. It is oily, of a faint acid and empyreum. odor, a sharp acid taste, volatile above 194° , and distilling without decomposition at 414° ; spec. grav. at $57^\circ = 1.247$; slowly soluble in water in all proportions; absorbs 1 eq. water from the air, forming crystalline hydrated acid, which is more volatile than the dry acid, and soluble in water, alcohol, and ether. Form. of the dry acid, $C_5 H_2 O_3 = Ct$, therefore isomeric with itaconic acid.

Citraconates. The neutral citraconates of potassa, soda, ammonia, strontia, and lime are soluble and difficult to crystallize. Dry ammonia forms with the dry acid a compound, $2 (C_5 H_2 O_3) + NH_3$, which, dissolved in water, crystallizes spontaneously as $2 (C_5 H_2 O_3) + NH_4 O + aq$.

Curac. of Baryta. The neutral salt is an anhydrous crystalline powder, BaO, Ct . The acid salt crystallizes from the hot solution in fine silky needles, $BaO, HO, 2 Ct + aq$. The acid salt of strontia has the formula $SrO, HO, 2 Ct + 3 aq$. The acid salt of lime has the same composition; that of magnesia is crystalline.

Citrac. of Lead, formed by precipitating in the cold, citrate of ammonia with neutral acetate of lead, is amorphous, and has the form. $PbO, Ct + 2 aq$, but if heated in the liquid it becomes crystalline, and is then PbO, Ct ; the solution filtered from the last deposits a voluminous powder, $PbO, Ct, + aq$. Besides these neutral there is a basic salt, formed by basic acetate of lead, nearly insoluble, crystalline, anhydrous. The salt of nickel is green, uncrystallizable; of cobalt red, crystalline; of manganese opaque, tough; of protoxides of tin and mer-

cury white, sparingly soluble. The precipitate formed by nitrate of silver and citrate of ammonia is white, voluminous, amorphous, soluble in hot water, from which there separates first, fine, shining needles, anhydrous, AgO, Ct , and subsequently from the same liquid transparent, adamantine, 6-sided prisms with the formula $AgO, Ct + aq$; the water passes off at 212° .

CIVET. *Tech.* A substance analogous to musk in odor, and obtained from two species of animals, *Viverra Zibetha* and *V. Civetta*. Its odor is due to an essential oil, which may be separated by distillation.

CLARIFICATION. *Tech.* A process for rendering a turbid liquid clear by introducing another substance into it. Albumen, as in the white of egg or blood, when boiled in a liquid coagulates and collects the floating particles. It is applied to sugar-solutions, coffee, &c. Gelatine, isinglass, glue, when added to a cloudy liquid containing tannin, combines with it to an insoluble compound, enclosing floating matter at the same time; hence its use in fining beer, &c. Turbid river water may be clarified by a little alum. The Chinese put a small piece of alum in the hollow of a bamboo and stir the water a moment with it, when the suspended matter subsides in a short time. The process of simmering vegetable juices, as those of fruits, acts in part by the coagulation of the albumen contained in them, which rises to the top, carrying floating matter with it, and is then removed by skimming. Where the turbid liquid is passed through porous matter, it is **FILTRATION**.

CLAUSTHALITE. *Min.* See SELENIURET OF LEAD.

CLAY. *Geol. Min. Tech. Syn.* Argillaceous, Aluminous earth. *Ger.* Thon; *Fr.* Argile.

Geol. Clay is extensively distributed over the earth, often in heavy beds, and is mainly due to the decomposition and wearing of rocky masses, the finer particles of which, transported by streams, form local deposits in rivers and bays, and more extensive deposits in the bed of the ocean. From its origin it necessarily varies in composition and character. It is pulverulent, emits a peculiar odor, termed argillaceous, when breathed on, forms a soft, plastic mass with water, and is then usually unctuous to the touch. It is composed mainly of silica and hydrous alumina, the silica being partly hydrous and partly as sand, together with smaller quantities of potassa, lime, magnesia, oxide of iron, &c.

Min. Some local deposits of clay appear to be definitely constituted, and it is not improbable that all clays consist of one or more of clays composed according to regular formulas. See ALLOPHANE, BOLE, CIMOLITE, LITHOMARGE, KAOLIN, KOLLYRITE, &c. Berthier regards the hydrous silicates of alumina as compounds of 1 eq. hydrate of alumina, $Al_2 O_3, 3 HO$, with 1 or more eq. of different hydrous silicates of alumina, and divides them into two groups; Allophanes, in which the alumina has more, and Halloysites, in which it has less oxygen than the silica.

Tech. The clays are extensively applied in the arts, as the manufacture of porcelain, fine

CLAY.

CLAY.

and coarse pottery, stone-ware, crucibles, and brick. The following tables of the composition of clays are from Berthier's "Essais par la voie sèche."

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Silica.....	71.0	66.7	66.1	66.7	63.7	63.0	66.7	56.9	65.0	64.4
Alumina.....	19.0	18.2	19.8	21.6	20.7	23.0	24.0	21.9	24.0	24.6
Magnesia.....	—	0.6	—	—	—	—	1.2	0.6	—	—
Oxide of iron..	—	1.6	6.3	2.5	4.0	1.3	1.2	3.4	trace	trace
Water.....	9.0	12.0	7.5	9.0	10.3	12.0	6.6	17.4	11.0	10.0
	99.0	99.1	99.7	99.8	98.7	99.3	99.7	100.2	100.0	99.0

	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
Silica.....	61.7	54.0	55.4	52.0	58.2	55.9	54.0	52.0	48.4	50.0
Alumina.....	24.7	25.0	26.4	27.0	28.0	26.8	30.0	31.6	30.0	32.7
Magnesia.....	—	trace	—	—	—	2.5	—	—	—	1.5
Oxide of iron..	2.2	6.0	4.2	2.0	3.5	1.0	—	4.4	2.2	—
Water.....	10.0	14.0	12.0	19.0	10.0	13.6	15.6	12.6	18.0	16.0
	98.6	99.0	98.0	100.0	99.7	98.9	99.6	100.6	98.6	100.2

	21.	22.	23.	24.	25.	26.	27.	28.	29.	
Silica.....	47.2	49.2	49.2	50.6	46.9	49.6	46.5	50.5	57.0	
Alumina.....	32.4	34.0	34.0	35.2	36.4	37.4	34.9	12.8	10.3	
Magnesia.....	—	—	—	—	1.0	—	—	4.0	3.0	
Oxide of iron..	3.0	—	—	4	—	—	3.0	7.0	6.7	
Water.....	16.0	16.4	16.4	13.1	14.8	11.2	15.2	25.7	23.0	
	98.6	99.6	99.6	99.3	99.1	98.2	99.6	100.0	100.0	

No. 1, from Antragues, near Jemmapes, in Belgium, grayish white, somewhat unctuous, excellent for glass-pots. 2. Pipeclay, from Strasburg, gray, unctuous; it contains 1.5 per cent. sand in addition to the rest. 3. From Hayanges, dep. Moselle, yellowish, sandy, used for fire-brick. 4. From St. Amand, dep. Nièvre, yellowish, used for common pottery. 5. Stour-bridge, gray, excellent for crucibles for glass and steel. 6. Cimolite, analyzed by Klaproth. 7. Pipeclay, near Cologne, white, soft, with 0.3 per cent. sand in the analysis; accompanied by lignite. 8. From Hæganäs, Sweden, analyzed by Karsten, slaty, very refractory, from a coal formation. 9. From Forges, dep. Seine-Inférieure, gray, becomes white by calcination, excellent for glass-pots, from a tertiary formation. 10. From Colonne, dep. Seine-et-Marne, white, mixed with sand, used for fine pottery. 11. From Montet, dep. Saône-et-Loire, grayish white, good for fire-brick and blast furnaces. 12. From Vanvres, near Paris, gray, becoming reddish by calcination, used for laboratory-furnaces, &c. 13. From Bouchade, dep. Allier, yellowish white, good for glass-pots for bottle-glass. 14. From Andennes, Belgium, gray, soft, used for brass-crucibles.

15. From Clarac, dep. Aveyron, gray. 16. From Plaignes, dep. Seine-et-Marne, white. 17. From Vire, dep. Calvados, gray, whitening by calcination, with very little sand, used for fulling. 18. From Leyval, dep. Charente-Inférieure, white, slightly red-marbled, excellent for glass-pots. 19. From Argentières, dep. Indre, very white. 20. From Frankfort am Mayn, gray, used for alum. 21. From Nuzejoul, dep. Lot, pale blond, used for glass-pots. 22. From St.-Aulin-les-Foux, dep. Seine-Inférieure, of a chocolate color when dry, whitening by calcination, used in Sweden for brass-crucibles. 23. From Echassières, dep. Allier, white, used for crucibles for fusing ores of antimony. 24. From Abondant, dep. Eure-et-Loir, gray, used for porcelain seggars at Sèvres. 25. From Angleur, Belgium, very white. 26. From Devonshire, grayish white, whitening by calcination, very refractory. 27. From Gross-Almerode, Hessia, gray, becoming pale reddish-gray by calcination, used for making Hessian crucibles. 28, 29. Fuller's earth from England, 28 being the better quality, white with greenish tint.

The following analyses of Kaolin are from the same authority.

	1.	2.	3.	4.	5.	6.	7.	8.
Silica	46.8	43.6	52.8	55.8	63.5	50.0	46.0	45.06
Alumina	37.3	37.7	31.2	25.0	28.0	28.0	39.0	32.00
Potassa	2.5	—	2.2	3.2	1.0	2.2	—	—
Lime.....	—	—	—	—	—	5.5	—	0.74
Magnesia.....	trace	—	1.6	8.5	8.0	0.7	—	—
Oxide of iron.....	—	1.5	—	1.8	—	5.5	$\frac{1}{2}$	0.90
Water.....	13.0	12.6	10.0	7.2	—	9.5	14.5	18.00
	99.6	95.4	97.8	99.5	100.5	101.4	99.5	96.70

CLAY-SLATE.

1. From St. Yriex, dep. Haut-Vienne, used in the porcelain composition at Sèvres, and is then pure white. 2. From Schneeberg, Saxony, slightly reddish, the loss in the analysis includes alkali. 3. From Meissen, Saxony, very white. 4. From Garde-Fregney, dep. Var, reddish white, encloses felspar and mica. 5. From Fourches, dep. Lozère, faintly reddish, enclosing feldspathic sand. 6. From Normandie, much colored by oxide of iron. 7. From Ane near Schneeberg. 8. From Passau in Bavaria.

Brogniart divides clays into Refractory, Fusible, Effervescing, and Ochrey. 1. Refractory, or Fire-clays. They are infusible at any furnace heat, merely cohering, and often scarcely cohering, and contain little or no oxide of iron. They embrace Kaolin, and Plastic or Pipe-clays, together with Lithomarge, Cimolite, Kolyrite, &c. They are employed in the manufacture of porcelain, pipes, fine pottery, glass and other crucibles.

2. Fusible clays are more or less fusible at high furnace heats, and contain more or less oxide of iron, magnesia, and lime, which are the cause of their fusibility. They include Fuller's earth, Potter's clay, and clay for bricks, and are used for the manufacture of common pottery, brick, &c.

3. Effervescing clays or Marls, are mixtures of clay and carbonate of lime; they effervesce with acids, are fusible; they are employed as an addition to other clays in making coarse pottery and brick, as a manure in agriculture, &c.

4. Ochrey clays are colored by oxide of iron, sometimes combined with an organic acid. They include Ochres, Bole, and Reddle, which are mainly used as pigments or crayons. See BRICK, POTTERY, PORCELAIN, MARL, &c.

CLAY-SLATE. *Geol.* A clay formation, hardened by lapse of time and other causes, constituting extensive deposits. It is frequently traversed by joints so numerous that the dip of the stratum cannot be accurately determined.

CLAY-IRON-STONE. *Min.* See SPARRY IRON.

CLEAVELANDITE. *Min.* See ALBITE.

CLINTONITE. *Min.* Foliated; the laminæ inflexible; reddish or brownish; lustre metallic, pearly; translucent, opaque; $H. = 4-4.5$. $G. = 3.07-3.1$; infusible alone; decomposed by acids. The analyses of it by Clemson and Thomson are too much at variance to allow of a formula, but it bears some analogy to Xanthophyllite. It occurs at Amity, Orange county, New York.

CLOVES. See CARYOPHYLLIN.

CNICIN. Occurs in *Cnicus benedictus*, (*Nativille*;) and in all *Cynarocephalæ*, (*Scribe*.) It crystallizes in transparent white needles, which have no smell, a bitter taste, are neutral, not affected by exposure to air, fuse and are decomposed by heat; little soluble in cold, more so in boiling water; the solution deposits, on long boiling, a tenacious body; alcohol dissolves it readily, ether sparingly. It consists of 62.9 C, 6.9 H, 30.2 O. *Ch. Gaz.* ii. 462.

COAGULUM. *Ger.* Gerinnsel, is generally applied to a jelly separating from a liquid.

COAL.

Albumen is coagulated by heat. See ALBUMEN, CLARIFICATION, and BLOOD.

COAK. See COKE.

COAL. *Geol. Chem. Tech. Syn.* Lignite, Pit-coal, Stone-coal, Anthracite. *Ger.* Steinkohlen; *Fr.* Charbon, Houille.

Geol. The various kinds of coal constitute extensive formations in many parts of the globe, but few of which have been extensively mined and usefully applied. They are black or brownish black, hard to rather soft, brittle, burning more or less freely with more or less flame, and, together with the adjacent slates, abounding with impressions of leaves and stems of fern, &c. From several points of view we distinguish 3 kinds, Lignite, Pit-coal, and Anthracite, which exhibit a striking similarity in different localities.

Lignite, or brown coal, belongs to the Tertiary formation, and is sometimes heavy-bedded, in nests, rarely forming an extensive field, has usually a brown streak, burns with a dark smoky flame and much disagreeable odor; it appears to be vegetable matter less altered than the following kinds. Lignite sometimes occurs as carbonized stems of trees, disseminated in clay, and is associated with amber, retinasphalt, &c. In the United States the Richmond coal is of this character, besides disseminated trunks of trees in the Red Clay formation extending from Amboy far to the southwest. Lignite is also found and mined in Germany, France, England, China, &c.

Pit-coal, or Bituminous coal, belongs to the secondary formations, and occurs in beds extensively developed, forming tracts of many thousand square miles in extent. It has usually a black streak, and is more shining than lignite; burns with a less or more smoky, but usually more brilliant flame, and less disagreeable odor, is more regularly stratified, and its organic origin is less distinctly seen. Several varieties are distinguished in England. *Cherry coal* breaks in cubical masses, is black, shining, burns freely; *caking coal* resembles cherry coal, but the fragments cement together in the fire by fusion; *splint coal* breaks readily with a slaty fracture, resisting cross fracture more powerfully, is dull-black, harder than the preceding, burns freely with much smoke; *cannel coal* is grayish or velvety black, dull or with feeble resinous lustre, fracture conchoidal, burns most freely, with a brilliant white flame. The localities of pit-coal are the United States, Great Britain, Germany, South America, China, &c.

Anthracite belongs to the same formations as pit-coal, forming thick, continuous beds of great extent, is black, with a shining lustre, often submetallic and brilliant, breaks in more irregular masses than pit-coal, with a conchoidal fracture, is the hardest and toughest of all the coals, is ignited with more difficulty, but burns readily in masses with little flame. See ANTHRACITE.

Chem. Composition. Ammonia is always a product of the dry distillation of bituminous and brown coals, but the nitrogen is not an essential constituent, for analyses of the pure coals exhibit only traces of it, and we may attribute it to the remains of animal matter

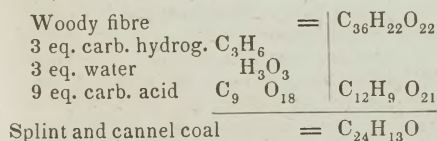
COAL.

enclosed within them. The following table contains the analyses of coals and turf made by Regnault and Richardson.

	Carbon.	Hydrogen	Oxygen and Nitrogen.	Ashes.
Turf.....	58.09	5.93	31.37	4.61
Lignite.....	71.71	4.85	21.67	1.77
Splint coal..	82.92	6.49	10.86	0.13
Cannel coal.	83.75	5.66	8.04	2.55
Cherry coal.	84.84	5.05	8.43	1.68
Caking coal.	87.95	5.24	5.41	1.40
Anthracite..	91.98	3.92	3.16	0.94

The analysis of brown coal or lignite, free from bitumen, gives the formula $C_{33}H_{21}O_{16}$, of splint coal from Newcastle, and cannel coal from Lancashire, $C_{24}H_{13}O$, of caking coal from Newcastle, $C_{20}H_9O$.

Origin. The presence of numberless impressions of leaves and stems of plants, both in and adjacent to coals, indicate their vegetable origin, and we may trace out chemically the changes which have resulted from the conversion of woody fibre into coal. Woody fibre is composed of $C_{36}H_{22}O_{22}$, and by comparing it with mouldered oak, it is found that an eq. of carbonic acid has been formed for every 2 eq. of hydrogen oxidized by the air. Comparing the formula of woody fibre with that of brown coal, we find that for 1 eq. of hydrogen oxidized, 3 eq. of carbonic acid are set free; thus $C_{36}H_{22}O_{22} + O = C_{33}H_{21}O_{16} + HO + 3CO_2$. But the splint and cannel coals are formed differently from brown coal, the change taking place probably without access of air, and consisting in the removal of 3 eq. carburetted hydrogen, 3 eq. water, and 9 eq. carbonic acid; thus:



Caking coal may be formed from cannel coal by the removal of olefiant gas, thus $C_{24}H_{13}O - C_4H_4 = C_{20}H_9O$. Now it is observed that carbonic acid is freely developed near brown coal formations, and may be the source of the carbonated mineral springs, and of the choke damp in mines. Moreover, the gaseous matter in coal mines, called fire-damp, consists of light and heavy carburetted hydrogen, carbonic acid, nitrogen, &c. The last may be due to the atmosphere or to the nitrogen in the coal. The constant occurrence of fire-damp seems to point out a change still operating, and if we suppose carburetted hydrogen and a little carbonic acid to continue passing off, the residue would be anthracite.

The above view of the changes which have occurred must be only viewed as approximately correct, and merely designed as an illustration; for it should be observed that some assume the composition of lignin or woody fibre to be $C_{36}H_{24}O_{24}$, and not as above given; and moreover, the above formulas will probably not hold good for the same kind of coal.

COBALT.

Tech. All kinds of coal are employed as FUEL, both for domestic use and in the arts. They are at the same time employed as reducing agents, in which the carbon seems to be the active agent. The bituminous coals subjected to heat in close vessels give rise to gaseous and liquid products, while Coke remains.

Products of Dry Distillation. These products are somewhat analogous to those derived from wood, and some are identical with them. Thus the gaseous products are light carburetted hydrogen, or marsh gas, olefiant gas, and carbonic acid. The liquid products consist of various bodies closely analogous to petroleum, and the solids consist of NAPHTHALINE and PARAFFINE. The relative proportions of these products vary with the temperature. The lower the heat employed, the less gas, and the more solids and liquids are produced; the higher the temperature, the greater is the quantity of carburetted hydrogen; but, for the purposes to which the practical process is applied, the temperature must not be raised too high, for then the gas evolved would be mostly marsh gas and pure hydrogen, which possess little illuminating power, while a great deal of illuminating power may be derived from the vapors of some highly volatile liquid products. From the aluminous constituents of the wood, or enclosed animal matter, coal always contains a small quantity of nitrogen, and hence ammonia is evolved in its distillation. The gas liquor so obtained is extensively used in the manufacture of sal-ammoniac. A small quantity of sulphur always exists in coal, which is evolved during the distillation as sulphuretted hydrogen. The liquid products have been examined by Runge and Laurent. The former found CARBOLIC ACID, (see also PHENYL,) KYANOLE, LEUCOLE, PYRROLE, and ROSOLIC ACID. Refer to the articles indicated, and to Illuminating GAS, Carburetted HYDROGEN, &c.

COBALT. *Ger.* Kobalt, Kobold. Some compounds of this metal, probably only its ores, were known and employed by the Romans, Greeks, and, probably, by the Egyptians, for analysis has shown its presence in some ancient blue glass. The ores have been used from the 16th century in the preparation of smalt, and Brandt first obtained the metal impure in 1733. It is not very abundant, being found chiefly as arseniuret in Cobalt-glance and Arsenical Cobalt, farther as Cobaltic Manganese, Cobalt-bloom, Cobalt Pyrites, &c.

Metallurgic Treatment of the Ores.

The ores containing arsenic are generally calcined to expel the arsenic. The operations vary according as the object is oxide of cobalt, or smalt, zaffre.

Oxide of Cobalt. 1. The roasted ore is dissolved in nitric acid, filtered from arsenious acid, &c., evaporated nearly to dryness, water added, again filtered, and sulphuretted hydrogen passed through; the filtered liquid is boiled, precipitated by carbonate of soda, filtered, and the carbonates of nickel, cobalt, and iron digested in oxalic acid, which removes the iron, after washing; the oxalates of cobalt and nickel are dissolved in caustic ammonia, and exposed

to the air for some days, when oxalate of cobalt is alone in solution; the solution is evaporated and ignited. By repeating the operation of solution in ammonia and exposure, the oxalates of cobalt and nickel may be entirely separated. (*Laugier.*) 2. The nitric solution of the unroasted ore evaporated, diluted and filtered, is treated with carbonate of potassa until the color of the precipitate shows that oxide of cobalt is falling down; to the filtered liquid a saturated solution of binoxalate of potassa is added, when in a few hours all the cobalt with a little nickel precipitates. (*Quesneville.*) 3. Precipitate the diluted nitric solution of the roasted ore with sulphuretted hydrogen, filter, boil, precipitate by carbonate of potassa, digest the precip. with ammonia, filter, dilute, add sal-ammoniac, then potassa, boil until a filtered test no longer precipitates, filter, and evaporate, when the oxide of cobalt deposits. (*Wittstein.*) 4. Fuse 3 pts. bisulphate of potassa in cast iron or earthenware, add gradually 1 pt. finely powdered and roasted ore, heat more strongly until the vapors of sulphuric acid cease to rise, pour out the liquid mass, dissolve it in boiling water, filter from arseniate of iron and cobalt, precipitate copper, &c., from the liquid by sulphuretted hydrogen, and precipitate nearly pure carbonate of cobalt by carbonate of potassa. The addition of a little green vitriol previous to fusion prevents the formation of arseniate of cobalt. (*Liebig.*) 5. Fuse 1 pt. pulverized, uncalcined ore with 3 pts. potash and 3 pts. sulphur in a clay-crucible at a gentle heat, treat it with water repeatedly, repeat the fusion and extraction of sulpharsenate of potassium with water, dissolve the residue in nitric, or dilute sulphuric with nitric acid, and precipitate with carbonate of soda. (*Wöhler.*) 6. For the cobaltic manganese ore, treat successively with muriatic acid, sulphuretted hydrogen, acetate of soda, and sulphuretted hydrogen. (*Wackenroder.*)

Smalt, Azure, Zaffre. Ger. Smalte, Blaue Farbe, Safflor, Zaffer. The materials employed are ore, quartz, potash, and arsenious acid. 1. Ore. From the expensive character of cobalt, and the want of heavy beds of it, the ores are carefully selected and assorted. The purest ores may be fully calcined, while the poorer can only be roasted to a certain point; in the latter case a portion of the fused metals remains in a mineralized state, called *Speise*, in making smalt. The ores, rich in nickel, are exposed to slow oxidization in the air for a year, whereby the iron, cobalt, arsenic, and sulphur get oxygenated by the atmospheric moisture, but the nickel continues in the metallic state. The ore increases in weight from 8 to 10 per cent. Pl. IV. figs. 9 and 10 are a vertical and horizontal section of the reverberatory for calcining cobalt ore. It is constructed for wood fuel, and the hearth is composed of fire-bricks or tiles. The vapors and gases disengaged in the roasting, pass off through the flues *aa* into the channels *bb*, and thence by *c* into the common vent, or poison chamber. See Pl. III. figs. 6, 7, and 8 for the condensing chambers, under ARSENIC. The flues are cleared out by means of openings left in suitable situations.

The calcination is carried on chiefly in winter, in order that the external cold may favor the more complete condensation of the arsenious acid. From 3 to 5 cwt. of Schlich (pasty ore) are roasted at one operation, and its bed is laid from 5 to 6 inches thick. After two hours, it must be turned over; and the stirring must be repeated every half hour, till no more arsenic is observed to exhale. The process being then finished, the ore must be raked out of the furnace, and another charge introduced. The duration of the roasting is regulated partly by the proportion of sulphur and arsenic present, and partly by the amount of nickel; which must not be suffered to become oxidized, lest it should spoil the color of the smalt. The latter ores should be but slightly roasted, so as to drive the nickel into *speise*. The roasted ore must be sifted. The loss of weight in the roasting amounts, upon the average, to 36 per cent. The roasted ore has a brownish gray hue, is called *safflor*, and is distributed into different sorts, FFS being the finest; FS fine; OS ordinary; and MS middling. These varieties proceed from various mixtures of the calcined ores. The roasted ore is ground up along with sand, elutriated, and, when dry, is called *saffre*.

2. The quartz is ignited, quenched, stamped, washed, ignited, and sifted, by which it loses some 30 per cent. of its weight. 3. The potash must be pure, freed from earthy matters, ignited. Soda cannot be substituted for it, as it yields a purplish color. 4. Arsenious acid is added, mainly to peroxidize the iron and prevent injury to the blue color.

The fusion of the cobalt glass is performed in glass-pots in an ordinary glass furnace. Pl. IV. figs. 11 and 12 represent a round smalt furnace, in two vertical sections, at right angles to each other. The fire-place is vaulted or arched; the flame orifice *a*, is in the middle of the furnace; *b* is the feed hole; *c*, a tunnel which serves as an ash-pit, and to supply air; *d*, openings through which the air arrives at the fuel, the wood being placed upon the vault; *e*, knee holes for taking out the *speise* from the pot bottoms; *f*, working orifices, with cast-iron plates, *g*, in front of them. Under these are the additional outlets *h*. The smoke and flame pass off through the orifices *i*, which terminate in expanded flues, where the sand may be calcined or the wood may be baked. Eight hours are sufficient for one vitrifying operation, during which the glass is stirred about several times in the earthen melting pots. A furnace of 8 pots produces from 24 cwt. of the mixture 19 cwt. glass, and $\frac{1}{2}$ to $\frac{3}{4}$ cwt. *speise*. When the glass is good and the *speise* has settled, the glass is taken out in iron ladles, poured into water, stamped dry, or crushed between rollers, sifted, ground between stones in water, and washed over, by which it may be obtained of different degrees of fineness. The purer the cobalt, the richer and purer the blue tone of smalt; a little nickel imparts a violet tone. Prussia produces annually about 370 tons, and Saxony about 500 tons of smalt. A superior quality is also produced in Sweden from the pure Tunaberg ores. Azure blue and smalt are used as a pigment, being rich in tone

and unchangeable by atmospheric and most chemical agents, for bluing linen, mixed with starch in common washing, for bluing paper, &c., for which last purpose it should be rejected, as its hardness wears a pen too rapidly.

COBALT AND METALLOIDS.

Cobalt. Oxide of cobalt may be reduced to metal by igniting the oxide in hydrogen, by powerful ignition in a charcoal crucible with a pure leadless glass as flux, by igniting oxalate of cobalt in a crucible under pure glass. It is reddish gray, with feeble lustre, magnetic (not magnetic, when pure, *Faraday*), as malleable as cast iron, with a little arsenic, it is brittle; spec. grav. = 8.49 to 8.53. Sym. Co. Eq. = 29.5 (29.57 or 368.99 O = 100).

1. *Protoxide of Cobalt.* Syn. Oxide of Cobalt. *Ger.* Kobaltoxydul. It is formed by igniting the carbonate in a tube filled with it and drawn out; it has a greenish color; by heating 1 pt. of the oxide with 4—6 pts. potassa in a silver crucible for a few minutes to commencing redness, the protoxide remains, after washing, in the form of square plates. *Hydrate.* The oxide is precipitated in a vessel apart from the air by caustic potassa of a blue color, probably a basic salt, which passes soon, especially by boiling, into the rose-red hydrate; or it may be formed by boiling the carbonate with potassa. It is apt to become brownish in drying, and loses its water above 212°. Form. CoO , HO , Eq. 46.5.

Salts. They are readily formed by dissolving the metal or carbonate in acids, or by precipitation; the soluble are carmine-red, the insoluble peach-red or violet. The metal is precipitated from most neutral solutions by zinc and cadmium; the black sulphuret is not precipitated from acidulated solutions in strong acids by sulphuretted hydrogen, but more or less perfectly from neutral solutions of feebler acids; the salts are perfectly precipitated by alkaline sulphurets except the persulphurets, in excess of which sulphuret of cobalt redissolves; ammonia precipitates them at first, soluble in an excess; carbonated alkali precipitates them peach-red, soluble in an excess; they are farther precipitated by phosphate of soda in the cold, by hydrates of protoxide of tin, of oxides of lead and mercury, when boiled; oxalic acid and alkaline oxalates throw down rose-red oxalate after some time; tincture of galls precipitates the acetate reddish brown, not the salts of stronger acids; yellow prussiate produces a green, red prussiate a brownish red precipitate, insoluble in muriatic acid.

Analysis. Besides the above behavior of the oxide in salts, it may be recognised by the blowpipe, and with more certainty and ease, from its imparting a blue color to borax and mic. salt in both flames, and when the quantity of oxide is considerable, the bead appears black: it is reduced with soda on charcoal to the metallic state. It may be separated by sulphuretted hydrogen when combined with a strong acid, and the solution is acidulated, from cadmium, lead, tin, bismuth, copper, silver, mercury, gold, antimony, and arsenic; by sulphhydrate of ammonia from the alkaline bodies; from manganese by alkaline persul-

phuret, which dissolves sulphuret of cobalt when the solution is neutral, or by adding acetate of soda to the mixed neutral solution, and precipitating sulphuret of cobalt by sulphuretted hydrogen; from zinc by converting them into acetates, adding an excess of acetic acid, and throwing down sulphuret of zinc by sulphuretted hydrogen; from peroxide of iron in the same way as manganese is separated by alkaline succinate, or by adding acetate of soda to the neutral solution and boiling, by which the iron salt separates; from nickel by the process No. 1 for preparing oxide of cobalt (see above). The oxide of cobalt ignited may be a mixed oxide; it is therefore weighed, a portion of it introduced into a bulb blown on the middle of a tube, dry hydrogen passed over it while ignited, and weighed as metal, from which the whole quantity of metal is calculated.

Use. Oxide of cobalt is employed to impart a blue color to glass, smalt, &c., most abundantly for the blue color on pottery and porcelain, where it combines with the alumina of the glazing or body, and is so fixed that it may be employed under the glazing of porcelain. Smalt, phosphate of cobalt, &c., are employed as blue pigments.

2. $\frac{4}{3}$ *Oxide of Cobalt.* When protoxide of cobalt, its nitrate, carbonate, or oxalate, is gently ignited in the air, the oxide then obtained is a compound of proto and peroxide; the peroxide is converted into it, with loss of oxygen, by a full red heat, whether exposed to the air or not. Probably the same compound is obtained as a dirty green hydrate by the action of the air on the hydrated protoxide. It is of a dark brown color, and does not unite with acids or alkalies. Form. $\text{CoO} + \text{Co}_2\text{O}_3 = \text{Co}_3\text{O}_4$.

3. *Peroxide of Co.* Sesquioxide. It is obtained anhydrous by gently igniting nitrate of cobalt, or by decomposing the chloride by carbonate of soda; a brown powder with the formula Co_2O_3 . The hydrate is obtained when chloride or nitrate of cobalt in solution is decomposed by hypochlorite of lime, or chlorine is transmitted into water in which proto-carbonate or hydrate is suspended, $3\text{CoO} + \text{Cl} = \text{Co}_2\text{O}_3 + \text{CoCl}$. It is black, yields the anhydrous peroxide by exposure to 600° or 700°; but it is difficult to drive off all the water, without also losing oxygen, and becoming CO_2O_3 ; it combines with no acid permanently, and when digested with hydrochloric emits chlorine, and chloride of cobalt is generated; other acids form with it salts of the protoxide. Formula, $\text{Co}_2\text{O}_3 + 2$ or 3HO .

4. *Cobaltic acid.* When a salt of cobalt is treated with ammonia in close vessels, part is dissolved, and part subsides in form of a blue powder. On admitting atmospheric air, this substance passes to a higher state of oxidation, and is gradually dissolved. If nitrate of cobalt is used, a double salt may be obtained in crystals, which appear to consist of nitrate and cobaltate of ammonia. *Gmelin.*

Two other mixed oxides are described by Winckler with the formulas Co_6O_7 and Co_8O_9 .

1. *Protosulphuret of Co.* Formed in the dry way by throwing fragments of sulphur on the ignited metal, or by igniting the protoxide with

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sulphur; and it is thrown down as a black precipitate from the salts of cobalt by alkaline sulphohydrates, or even by sulphohydric acid, if the salt is neutral, or the oxide united with a feeble acid. Prepared in the dry way, it has a gray color, metallic lustre, and crystalline texture. Form. CoS .

2. *Oxysulphuret of Co.* When hydrogen is transmitted over sulphate of cobalt heated to redness, water and sulphurous acid are evolved, and a compound remains, called an oxysulphuret, consisting of oxide of cobalt united with sulphuret of cobalt. Form. $\text{CoO} + \text{CoS}$.

3. *Sesquisulphuret of Co.* Formed by heating 2 to ignition in sulphuretted hydrogen, or oxide of cobalt in the same gas not to ignition, or by igniting oxide of cobalt, 2 or 3, with sulphur and potassa and extracting with water. See COBALT PYRITES. Form. Co_2S_3 .

4. *Bisulphuret of Co.* Prepared by heating 2 pts. carbonate of cobalt mixed with 3 pts. of sulphur in a glass retort to below redness, and continuing the heat as long as sulphur is expelled. Form. CoS_2 . *Setterberg.*

Phosphuret. A very basic compound is prepared by igniting 1 pt. cobalt, 1 pt. glacial phosphoric acid, and $\frac{1}{16}$ pt. charcoal powder, or 7 pts. metal or oxide, 10 pts. bone-ash, 5 quartz, and 1 charcoal for 1 hour in a blast-furnace. Shining, white, metallic, brittle, fusible with a fibrous structure. Another phosphuret is obtained by passing hydrogen over heated phosphate of cobalt; $3\text{CoO}, \text{PO}_5 + \text{H}_8 = \text{Co}_3\text{P} + 8\text{HO}$; or by the action of phosphuretted hydrogen on chloride of cobalt. Form. Co_3P .

Alloys. Cobalt alloys readily with arsenic, forming white compounds. An alloy is found at the smalt-works of Modum, Norway, in needles tables with metallic lustre, composed of 5 Co (Fe, Cu) + As. It also combines with antimony, gold, mercury, copper, tin, zinc, nickel, and iron.

HALOID SALTS.

Chloride of Co. 1. Formed by igniting the metal in chlorine; 2, by solution of the oxide or carbonate in chlorohydric acid. It may be sublimed in crystalline scales. Blue or greenish blue, deliquescent, becoming rose-red by combination with water; the solution duly concentrated yields oblique rhombic crystals, carmine red, deliquescent, becoming blue by concentrated sulphuric or chlorohydric acid. Form. of the anhydrous chloride, CoCl . It absorbs ammoniacal gas, becoming $\text{CoCl}, 2\text{NH}_3$. Chloride of cobalt forms a beautiful sympathetic ink, which is employed when moderately diluted, so that on drying in the air, the letters are scarcely perceptible, but when gently warmed the salt becoming anhydrous appears of a rich blue color.

Iodide of Co. Formed by heating the metal and iodine, is greenish, fusible, forming with a little water a brown, with more water a red solution, soluble in alcohol. Form. CoI .

Bromide of Co. Formed in the dry or moist way, is green when dry, violet when moist, red in solution, deliquescent, decomposed by fusion; precipitable by ammonia, but redissolved in the excess.

1. *Fluoride of Co.* Obtained by solution of

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the oxide in fluohydric acid, and evaporation, in small, irregular, rose-red crystals, soluble in a little water. Form. $\text{CoF}, 2\text{HO}$. Decomposed by much water, leaving an oxyfluoride of a pale red color with the formula $2(\text{CoO}, \text{CoF}) + \text{HO}$.

2. Cobaltofluorides of potassium and ammonium are pale red, crystalline, granular, sparingly soluble.

3. *Silicofluoride of Co.* Formed by solution of the carbonate in silicofluoric acid, forms pale red rhombohedra and 6-sided prisms, very soluble in water. Form. $3\text{CoF}, 2\text{SiF}_3 + 7\text{HO}$.

OXYALS.

1. *Sulphate of Co. a. Neutral.* Obtained by dissolving the carbonate or oxide in dilute sulphuric acid, and concentrating the solution. Deep carmine red, oblique rhombic prisms, isomorphous with sulphate of iron; taste somewhat sharp, bitter, and metallic; when heated they become opaque without melting, and may be exposed to a red heat without losing their acid, soluble in 24 pts. cold water, insoluble in alcohol. Glacial acetic acid precipitates the sulphate totally from its solution. Form. $\text{CoO}, \text{SO}_3 + 7\text{HO}$.

b. *Basic.* Precipitate a with an insufficient quantity of alkali; flesh-red, insoluble in water.

2. *Sulphate of Co.* forms with sulphates of potassa and ammonia red crystals, oblique rhombic, like the corresponding salts of magnesia; formula, $\text{KO}(\text{NH}_4\text{O})\text{SO}_3 + \text{CoO}, \text{SO}_3 + 6\text{HO}$.

3. *Hyposulphate of Co.* Obtained by decomposing the sulphate by hyposulphate of baryta and evaporating; indistinct crystals of a rose-red color, very soluble in water, not deliquescent. Form. $\text{CoO}, \text{S}_2\text{O}_5 + 6\text{HO}$.

4. *Sulphite of Co.* A basic salt is precipitated by boiling a salt of cobalt with sulphite of potassa.

5. *Hyposulphite of Co.* Precipitate the sulphate by hyposulphite of strontia, and evaporate the filtrate gently; it becomes bluish, deposits sulphur, and leaves a dark red crystalline mass, which by heat gives off water, sulphurous acid, and sulphur, leaving sulphuret of cobalt. Form. $\text{CoO}, \text{S}_2\text{O}_2 + 6\text{HO}$.

1. *Nitrate of Co.* Obtained by dissolving cobalt, its oxide or carbonate in nitric acid; the solution deposits red crystals; taste acid, bitter; dissolve readily in water; deliquesce in the air; when heated, they melt below 212° , give off water, and when the heat is increased nitrous fumes are given off, and peroxide of cobalt remains. Form. $\text{CoO}, \text{NO}_5 + 6\text{HO}$.

2. *Nitrate of Co. and Ammonia.* Rose-red cubical crystals, permanent in the air.

3. *Nitrate and Cobaltate of Amm.* Neutral nitrate of cobalt gives with ammonia a blue precipitate changing to green; the liquid browns in the air, and by continued agitation absorbs oxygen, the green precipitate redissolves, and the dark brown solution deposits brown 4-sided prisms, which evolve oxygen by sulphuric or nitric acid. *Gmelin.*

1. *Phosphate of Co.* precipitates by double decomposition as violet flocks, soluble in phosphoric acid, ammonia, and slightly in ammoniacal salts. A pyrophosphate is also

precipitated by pyrophosphate of soda, soluble in excess of the latter. Oxide of cobalt dissolves readily in mic. salt with a deep blue color.

2. *Phosphite of Co.* is thrown down bright red from a cobalt-salt by a solution of terchloride of phosphorus neutralized by ammonia.

3. *Hypophosphite of Co.* The acid saturated with hydrated oxide of cobalt, filtered and evaporated in vacuo, yields red efflorescent 8- and 6-hedra, isomorphous with the salt of magnesia. Formula, $\text{CoO}, \text{PO} + 8 \text{HO}$. A double salt is formed by boiling hyposulphite of lime with an excess of oxalate of cobalt; the filtrate yields red efflorescent 8-hedra, composed of $2 (\text{CaO}, \text{PO}) + \text{CoO}, \text{PO} + 8 \text{HO}$.

Iodate of Co. Formed directly, is violet red, crystalline, soluble in 148 pts. water at 59° . in 90 pts. boiling water. Formula, $\text{CoO}, \text{IO}_5 + \text{HO}$. When dissolved in ammonia, alcohol precipitates a rose-red compound with ammonia.

Bromate of Co. Formed from sulphate of cobalt and bromate of baryta by evaporation; transparent hyacinth-red 8-hedra, isomorphous with bromates of magnesia, zinc and nickel, soluble in 2.2 pts. cold water. Formula, $\text{CoO}, \text{BrO}_3 + 6 \text{HO}$. It combines with ammonia.

Borate of Co. Formed by double decomposition, is reddish white, scarcely soluble in water, fusible to a dark blue glass. Borax fuses with the oxide to a similar glass.

Carbonate of Co. Precipitate a cobalt-salt boiling, by an excess of neutral or bicarbonate of potassa; peach-blossom red, insoluble in water, soluble in carbonated alkali, separating as crystals from carbonate of ammonia. Formula, $5 \text{CoO}, 2 \text{CO}_2 + 4 \text{HO}$.

Silicate of Co. A solution of water precipitates cobalt-salts blue. Smalt and blue glass is a compound of silicate of cobalt, &c.

Oxide of Cobalt with other Oxides.

Oxide of cobalt dissolves in fused potassa or soda to a blue liquid, which congeals to a brown (according to Gmelin to a blue) mass.

Rinnman's Green is prepared by precipitating a mixed solution of cobalt and zinc free from iron by carbonated alkali, washing, drying and igniting the precipitate strongly. The shade of green may be varied according to the proportion of the zinc salt.

Leitner's Blue is prepared by precipitating mixed alum, free from iron, and nitrate of cobalt by carbonated alkali, or by moistening pure clay with the nitrate and igniting strongly. In intensity, brilliancy, and durability, it is but little inferior to ultramarine.

Thenard's Blue is nearly the same as the preceding, but is made by mixing 1 pt. phosphate of cobalt with 8 pts. hydrated alumina, and igniting. Arseniate may be used instead of the phosphate. Or it may be made by evaporating nitrate of cobalt and ammoniacal alum to dryness and igniting. Magnesia or a magnesian mineral, unless alumina be present, ignited with nitrate of cobalt becomes pale rose-red. See BLOWPIPE, tests for bases.

COBALT BLOOM. *Min. Syn.* Prismatic cobalt-mica; Arseniate of cobalt; *Ger.* Kobaltblüthe. *Cryst. system.* Oblique Rhombic; the

crystals usually minute, often stellated needles. It occurs also earthy. $H. = 1.5 - 2$. $G. = 2.948$. Color red; lustre pearly, dull. It yields water in a closed tube; reduces to arseniuret on charcoal, giving off arsenical vapors, and gives the reaction of cobalt with the fluxes. Its formula is $3 \text{CoO}, \text{AsO}_5 + 6 \text{HO}$, (or 5HO). Laurent's analysis gives 9 HO. It occurs associated with other cobalt ores.

COBALT GLANCE. *Min. Syn.* Hexahedral cobalt-pyrites; silver or bright white cobalt; cobaltine. *Cryst. system,* Regular; usually as the $\frac{3}{4} \times 6$ -hedron, combined with the 8-hedron, 24-hedron and cube. $H. = 5.5$. $G. = 6.298$. Silver-white, with reddish tint and metallic lustre; brittle. In an open tube it evolves sulphurous acid, and sublimes arsenious acid; on charcoal gives off arsenical fumes, fusing to a gray globule; shows cobalt with the fluxes. Analysis of a specimen from Skutterud, Norway, by Stromeyer:

Sulphur.....	20.084
Arsenic.....	43.465
Cobalt.....	33.101
Iron	3.232

99.882

Its formula is $\text{Co As} + \text{Co S}_2$. It occurs at Tunaberg, Sweden; Modum, Norway, &c. This and arsenical cobalt are the two principal ores of cobalt.

COBALTIC MANGANESE. *Min. Syn.* Earthy cobalt. Botryoidal, earthy; bluish black; streak shining; $H. = 1 - 4$; $G. = 2.24$. This mineral can scarcely be regarded as pure, its composition being variable. It appears to consist mainly of peroxides of cobalt and manganese, although the latter may be wanting. The oxide of cobalt varies from 20 to 60 per cent. It occurs at several cobalt localities in Europe; a similar mineral is found at mine La Motte in Missouri, and is probably derived from the decomposition of cobalt pyrites.

COBALT PYRITES. *Min. Cryst. system,* Regular; as the cube combined with 8-hedron, &c. Steel-gray, metallic, with red tarnish. $H. = 5.5$. $G. = 6.3 - 6.4$. It gives off sulphurous acid on charcoal, fusing to yellow magnetic globule; and shows the presence of cobalt with the fluxes. It contains 43—53 per cent. cobalt, 39—43 sulphur, &c. Formula, $\text{Co}_2 \text{S}_3$ or $\text{CoS} + \text{Co}_2 \text{S}_3$. It occurs at Bastnäs, Sweden; Mine La Motte, Missouri; &c.

COCCOLITE. *Min.* See AUGITE.

COCCULUS INDICUS. *Tech. Chem. Syn.* *Cocculus menispermum*, *Cocculus levanticus* or *piscatorius*. The fruit of a tree growing upon the coasts of Ceylon, and imported from the East Indies in bags, and hence also called Indian berry. It is similar in appearance to the bay berry, but slightly smaller, and is distinguished therefrom by the semi-lunar form of the oleaginous yellow seed, which seldom entirely fills the cavity of its shell. It is sometimes employed as a dangerous and fraudulent sophistication of malt liquors, in order to increase their exhilarating influence; a most reprehensible practice, for the berries owe their active properties to a narcotic, poisonous, crystallizable principle, *picrotoxin* or *cocculin*.

which is bitter to the taste and of neutral reaction. Besides this, there is left in the alcoholic extract of the fruit, from which the cocculin has been dissolved by means of acidulated water, a brown resinous acid, called the *picrotoxic acid*. *Menisperm* and *Paramenisperm* are also constituents of the fruit, alike in composition, but dissimilar in certain properties, the former being crystallizable and capable of forming salts, while the latter, though crystalline, is unable to saturate acids, and is moreover less fusible and more insoluble in ether. The above-named, together with yellow alkaline, resinous and fatty matters, wax, gum, starch, chlorophylle, lignin, mucus, malic acid, odorous and inorganic matter, represent the composition of the berry. According to Meissner, crystals of *picrotoxin* are readily obtained by the evaporation of a decoction of the berries.

COCHINEAL. *Tech. Chem.* A dried insect, the *Coccus Cacti* of Linnæus, about one or two lines long, wrinkled, irregularly shaped, convex on one side, and flat or slightly hollow on the other. (*Pereira*.) This description applies to the female, which is twice as large as the male, and being free from the characteristic cottony covering of the latter, is less bulky, and consequently more valuable in coloring material. The animal is a native of Mexico, in certain provinces of which it is reared extensively with great care, and expressly as an article of commerce, and forms one of the most important items of export from that country. It feeds upon the *nopal* plant (*Opuntia Cochinelifera*), and at harvest time is brushed from the leaves with a feather into a vessel of hot water beneath, then drained and dried in the sun. There are three gatherings annually. In the first, the impregnated and enlarged females exclusively are collected, whereas of the remaining two, the former comprises the younger, and the latter a mixture of these and the male insect. There are two varieties of cochineal peculiar to both the Honduras and Vera Cruz species. The *Silver cochineal* (*Cochinilla jaspeada* of the Spaniards) has a purplish gray color, with a whitish dust deposited in all the furrows. *Black cochineal* (*Cochinilla renigida*, or *granatigra* of the Spaniards) is reddish or purplish black, and devoid, or nearly so, of the silvery character. (*Pereira*.) The name of *mesteque*, applied to the granilla species (*Cochinilla sylvestre*, or *grana sylvestria*), is after that of the Mexican province of Mistēca, where it is cultivated. These latter have a fragmentary appearance, but are really whole insects, of a small and globular shape. Pure cochineal is unalterable when kept in a dry place, but it is not unfrequently adulterated with dried dough and sulphate of baryta, especially that kind called East India cochineal. When freed of fat, by ether, and then extracted by water, it is, says Kastner, a good test for the protosalts of iron, which give to its solution a violet colour.

It is thought by Wittstein, that the color is extracted from the plant, and assimilated by the insect. Its chief use is in dyeing; the brilliant crimson color which it yields in every

variety of shade, rendering it much esteemed for this purpose.

The analysis of Caventou shows the constituents of cochineal to be *cochinellin*, *peculiar animal matter*, *fatty matter*, *salts of lime and potassa*, and *an organic acid*.

The coloring principle, called *cochinellin*, is soluble in water, from which it is precipitated by the acids in a reddish yellow powder. The alkalis color it violet, without occasioning any deposit, but the addition of alum throws down a brilliant red paste called *carmine*. *Cochinellin* is a brilliant purplish red crystalline substance, and though synonymous, is not identical with carmine, the latter being a compound of the former, animal matter, and an acid, together with a certain portion of hydrate of alumina, for which it has a remarkable affinity. The brilliant scarlet dye which it imparts to stuffs is produced by the action of an alum mordant, assisted by the admixture of a little tin salt (acid muriate of protoxide of tin), and cream of tartar (bi. tart. potassa), upon a strained decoction of the insects.

Notwithstanding the affinity of the red coloring principle for alumina, and the readiness with which it leaves its watery solution to form carmine and lake, yet the alumina is not essential to their formation, for both tin salt and binoxalate of potassa will give rise to similar products. Each owes its action to the excess of acid which it contains, both throwing down the coloring and animal matter together, and in the former instance connected with oxide of tin. Alumina serves to give bulk and weight to the carmine and decrease its cost; and the several grades of this article are regulated proportional to the admixture with this earth; the pure superior article being precipitated by an acid from an alkaline decoction of cochineal, which contains no alum; this latter being used only when the *pure carmine* is to have a *crimson* shade.

Carmine is used as a water color for various purposes in the arts, and when dissolved in vinegar forms the *vinaigre de fard* of the French. This and the *rouge liquide*, in which carmine is also an ingredient, are convenient but injurious cosmetic pigments.

Liquid carmine, the brilliant lustrous color of which causes its preference in velvet painting and as a fine red ink, is merely a solution of carmine in pure water of ammonia.

Below are several of the most available processes for making carmine.

1. *German process.* By alum alone. Boil 1 lb. powdered cochineal for 15 minutes in 1 gallon of water; then add 1 oz. pulverized alum, and again boil for 3 minutes; after which remove the vessel from the fire, and when it has settled decant the clear supernatant liquid into clean vessels and set them aside. After several days' repose, there will be a deposit of 1½ oz. of carmine; and by leaving the mother liquor still longer, an additional ½ oz., of inferior quality, will be obtained.

2. *French process.* To a decoction of 1 lb. of pulverized cochineal in 3 gallons of water, after having boiled for 15 minutes, add 1 oz. of

COCHLEARIA.

powdered cream of tartar; and again, after 10 minutes' ebullition, $\frac{1}{2}$ oz. of alum. Two minutes' additional boiling suffice, and the vessel being then removed from the fire, is allowed to settle for some minutes, and the clear decoction carefully decanted into clean glass vessels, which are to be set aside until the carmine deposits. It is then to be drained, and dried as usual in the shade.

3. *Madame Cenette's process for superfine carmine.* Mix 2 lbs. powdered cochineal, of best quality, with 15 gallons boiling distilled water, and after 2 hours' ebullition, add thereto 3 oz. bruised pure saltpetre, and after 3 minutes' additional boiling, 4 oz. salts of sorrel, (binxalate of potassa.) The whole having boiled ten minutes longer, and being then removed from the fire, is allowed to settle for 4 hours, when the clear liquor is to be carefully decanted into clean shallow bell-glasses, and set aside for 3 weeks. At the end of this time, the film of mould formed on the surface must be dexterously and carefully removed, without breaking or disturbing the liquid portion, which is then to be drawn off through a syphon. The precipitated carmine left at the bottom of the vessels, when drained and dried in the shade, is of superior brilliancy and beauty.

According to Pelletier, the more highly oxidized the tin salt the more beautiful the carmine. The dregs, or partially exhausted cochineal, as well as the mother waters, in all these processes, will, by proper treatment, yield the inferior lakes; for which purpose they are usually reserved by the manufacturers.

COCHLEARIA. *Phar. and Chem. Syn. Radix raphani rusticani*; commonly called *Horse-radish*; is the yellowish white root of the *Cochlearia Armoracia*, an indigenous plant, which flowers in May, and is used in medicine as a general stimulant. Its agreeable pungent taste and odor render it a palatable condiment for the table, and mixed with vinegar is in general use as a sauce. When distilled with water, it yields a pale yellow, heavy, volatile oil, which has the characteristic odor of the root, and is so powerfully vesicatory that one drop, when applied to the skin, will produce inflammation. Gutret, who analyzed the root, found its constituents to be *acid volatile oil, bitter resin, extractive, sugar, gum, starch, woody fibre, vegetable albumen, acetic acid, and acetate and sulphate of lime.* (*Pereira.*) The *Cochlearia officinalis*, or common scurvy-grass, an indigenous plant, occasionally used as a salad, also contains a volatile oil, and the same constituents as the above, in addition to minute proportions of hydrochlorate and sulphate of ammonia; the acetate of lime also in the former being in the latter root substituted by the nitrate.

Oil of Cochlearia, or *Horse-radish*, is the volatile ingredient of both species of the *Cochlearia*, and belongs to the class of sulphuretted essential oils; and though existing already formed in the horse-radish root, nevertheless is composed almost entirely of oil of mustard, and with which, according to Hubatka, it is identical, both in specific weight and behaviour towards reagents. By his analysis, 0.3328 grms. of oil afforded 0.5858 carbonic acid, and 0.1575 water, which corresponds ex-

CODEIN.

actly with the composition of the oil of mustard.

		Calculated.	Found.
8	equivs. Carbon.....	606.83	48.60 48.41
5	" Hydrogen ...	62.40	5.00 5.26
1	" Nitrogen....	177.04	14.18
2	" Sulphur.....	402.33	32.22
1	" Mustard oil.	1248.60	100.00

When pure, it is transparent, of a light yellow color, and has a spec. grav. of 1.01, a pungent odor and biting taste, and precipitates the salts of lead as sulphurets; is soluble in alcohol and ether, but only slightly so in water. Acted on by chlorine gas, there is a change, resulting in the formation of a thick, dark mass, hydrochloric acid, and chloride of sulphur.

The oil in time becomes entirely crystallized, is then fusible, and volatilizes without residue, but is less soluble in alcohol than before. (*Liebig.*)

COCO or COCOA BUTTER. A white fat, of the consistence of lard, obtained by pressure from the steamed nuts of the *Cocos nucifera* or *butyracea*, a species of palm tree, which, by incision into the spathe at the top of the stems, also yields a sweet liquor, from which, in India, is distilled the well-known intoxicating beverage called *Arrack*. Coco butter fuses at 72°, and congeals at 64.5°; rancidifies by exposure; and is saponifiable, though less easily than most fats; the resultant soap requiring for its separation from alkaline ley more saline matter than soap generally. Its great solubility in alcohol serves to distinguish it from other fats. Besides olein, it is composed of a solid constituent, supposed by some chemists to be stearin, but by Pelouze and Boudet as identical with elaidin, and a crystallizable acid, the *coco-stearic* or *cocinic acid*.

Cocinic Acid. *Syn. Coco-stearic, Cocoic, Cocinic.* When pure, is a brilliantly white inodorous body; fusible at 95°; unalterable by distillation; capable of ready union with bases to form salts; forms an excellent material for candles, which burn and look equal to the adamantine candles. The most available process of manufacturing it is given in Morfit's "Applied Chemistry." The butter is used for making marine soap.

COCO SOLUBLE; properly Cacao. *Tech.* Similar to Baker's prepared Cocoa, which is Cacao ground up with sugar, and thus rendered readily miscible with hot water.

COCOGNIDIC ACID. *Chem.* Forms quadrilateral colorless prisms, which have a sourish taste, and are obtained, according to Goebel, by treating the alcoholic extract of the seeds of the *Daphne Gnidium* with water, and evaporating the filtered solution.

CODEIN. *Chem. Codeia.* Discovered by Robiquet, in 1832. A vegetable alkaloid, and one of the proximate constituents of opium, deriving its name from the Greek word *κωδεία*, a poppy-head. It is a crystallizable base, and with acids forms salts which have the peculiar property, when taken inwardly, of causing a tickling sensation at the surface of the body; the same effect produced occasionally

COFFEE.

by muriate of morphia being due to the presence of codein, in which, as usually prepared, it is contained to the extent of one or more per cent. In composition, it differs from morphia, with which it was at first confounded, in containing one equivalent less of oxygen. Unlike morphia, it is soluble in water and ether; and is distinguished therefrom by its insolubility in solution of potassa, and its non-precipitation from a dilute liquid of the muriate by the addition of ammonia. An excess of codein, when added to a saturated aqueous solution, melts and forms an oleaginous mass, which on cooling becomes crystalline. It is an incidental product of Gregory's process for preparing morphia; it being separable from the mixed muriates of the two by the aid of aqua ammoniæ, which precipitates the morphia, and leaves the codein to be afterwards thrown down by caustic potassa. Merck obtains codein, by exhausting with cold alcohol the rough morphia precipitated by carbonate of soda; the liquid being then neutralized by sulphuric acid, and the alcohol dissipated by evaporation, water is added until a turbidness ensues; after which the mixture is filtered, and the clear solution running through evaporated to a syrupy consistence, and mixed with its volume of moderately strong solution of caustic potassa, and four times as much sulphuric ether. The whole being well shaken together in a close stoppered bottle several times, is then allowed to settle. The saturated ether being drawn off, gives, by evaporation, crystals of pure codein. A repetition of this treat-

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ment, with fresh ether, extracts all the codein from the syrupy mass. From an aqueous solution, codein crystallizes in colorless, transparent, regular octahedrons, which by heat lose 5.8 per cent. of water, (Liebig); the crystals from ether, on the contrary, melting at 302° without loss of weight. Form. $C_{35}H_{20}NO_5$.

CODFISH OIL. *Tech.* Is obtained from the liver of the common cod, (*Morrhua vulgaris*), and from all of that genus. The oil of *Jecoris aselli*, sometimes called cod-oil, is from the *Gadus aselli*. There are two kinds of oil, the *white* and *brown*; the latter being by Jongh subdivided in two species, the *light* and *dark brown*. The white oil spontaneously exudes from the unprepared liver, whilst the two latter kinds are procured by pressure, from the heated liver and intestines. Their specific at 64°. Both are soluble in ether, alcohol gravities vary but little, being 0.924 and 0.923 taking up but 6.9 per cent. of the brown, and 4.5 per cent. of the white. Its disagreeable odor is due to the presence of a peculiar volatile acid, the *phocenic* or *delphinic*; but according to some chemists, the butyric. Jongh's analyses, given below, show the presence of the constituents of the bile, and a new substance, *gaduin*. The medicinal virtues of the oil, in rheumatic and scrofulous diseases, are attributable to the iodine and bromine which it contains. In the arts, its principal application is in the dressing of leather.

Below are the quantitative results of Jongh's analyses.

	Brown.	Bright brown.	White.
Oleic acid, with <i>gaduin</i> and two other substances.....	69.78500	71.75700	74.03300
Margaric acid.....	16.44500	15.42000	11.75700
Glycerin.....	9.71100	9.07300	10.17700
Butyric acid.....	0.15875	—	0.07436
Acetic acid.....	0.12506	—	0.04571
Fellinic and cholinic acid, with some margarin, olein, and bilifulvin.....	0.29900	0.06200	0.04300
Bilifulvin, bilifellinic acid, and two peculiar substances.....	0.87600	0.44500	0.26800
A peculiar substance, soluble in alcohol of 0.968 sp. grav....	0.03800	0.01300	0.00600
A peculiar substance, insoluble in water, alcohol, and ether..	0.00500	0.00200	0.00600
Iodine.....	0.02950	0.04060	0.03740
Chlorine and traces of bromine.....	0.08400	0.15880	0.14880
Phosphoric acid.....	0.05365	0.07890	0.09135
Sulphuric acid.....	0.01010	0.08595	0.07100
Phosphorus.....	0.00754	0.01136	0.02125
Lime.....	0.08170	0.16780	0.15150
Magnesia.....	0.00380	0.01230	0.00886
Soda.....	0.01790	0.06810	0.05540
Iron.....	traces	—	—
Loss.....	2.56900	2.60319	3.00943
	100.00000	100.00000	100.00000

COFFEE. *Tech. Chem.* The well-known dried oval berries of the *Coffea Arabica*, a plant indigenous to Arabia Felix and Ethiopia, but cultivated in the East and West Indies and Brazil. Adulterations with roasted corn are detected by the blue color given to a cold decoction by the solution of iodine. Their ready imbibition of exhalations from other bodies renders it necessary, as preservative of the flavor of coffee, to keep the berries stored separately from other articles. The same precaution applies to teas.

Payen's analysis of 100 pts. raw coffee, gave

Cellulose.....	34.000
Hygroscopic water.....	12.000
Fatty substances.....	10 to 13.000
Glucose, dextrine, and veg. acid.....	15.500
Legumin, caseine (glutine) ?.....	10.000
Chlorogenate of potassa and caffen. 3.5 to 5.000	
Nitrogenous substance.....	3.000
Free caffen.....	0.800
Concrete essential oil.....	0.001
Aromatic fluid essential oil.....	0.002
Mineral substances.....	6.697

According to Payen's analysis, *Caffein* is represented by the formula, $C_8H_{10}N_2O_3$; and a portion of it exists in the coffee, acting the part of a base, in a natural combination with potassa, and an organic acid called the *chlorogenic*, from its remarkable property of developing an intense green color. This double salt, the chlorogenate of potassa and caffein, is soluble in alcohol, in a ratio increasing with the proportion of aqueous dilution; and it crystallizes from its boiling solution in prisms, radiating from centres, or in warty groups. In anhydrous alcohol it is scarcely soluble, even at the boiling temperature. The double chlorogenate contains

Chlorogenic acid.....	63.5
Potassa.....	7.5
Caffein.....	29.0

This compound exists, in the normal state, in the perisperm of the fruit.

Chlorogenic Acid. $C_{14}H_8O_7$. This is obtained by precipitating the double salt with a solution of acetate of lead, and decomposing the resulting deposit by a stream of sulphuretted hydrogen gas. The solution remaining, when quickly evaporated, gives a mass of impure crystals of acid. Purification can be effected by recrystallization from alcohol or water, in either of which it is soluble.

Of the two *essential oils*, one only constitutes the agreeable aroma of coffee, and to the proportions of this component is owing the principal difference between Mocha and the inferior qualities of coffee. The fatty matter which retains both of them, is modified in its properties even by slight roasting; and the quantity of volatile empyreumatic hydrocarbon simultaneously generated during the process, increases as the roasting of the coffee has been carried beyond the point when the loss in weight amounts to 18 per cent. Pfaff attributed the aroma of roasted coffee to the decomposition and volatilization of caffein, but the experiments of Payen ascribe it to the volatile oil above mentioned, eliminated during torrefaction. The pleasantness of the drink, therefore, is dependent upon the nicety with which the berry has been roasted; for if too much heat is used, empyreumatic hydrocarbon will be generated, in quantity sufficient to overpower the flavor of the natural aroma.

Schrader's analysis of 100 pts. roasted coffee, gave

Coffee principle.....	12.50
Extractive.....	4.80
Gum and mucilage.....	10.42
Oil and resin.....	2.08
Solid residue.....	68.75
Loss.....	1.45

Payen (Jour. de Pharm. 1846) has given some advantageous advice as to the proper manner of roasting coffee. He directs the whole mass to be quickly heated to about 482° F. Under the influence of this temperature, and of the aqueous vapor disengaged during the operation, the tissues of the perisperm are disaggregated, and a portion of the caffein combined in the double chlorogenate is eliminated. There is also a slight caramelization of the cellulose and its allied substances, with an accompanying production of empyreuma. The

fatty oils being diffused through the then porous mass, carry with them the slightly modified essential oils, and hence become exposed over great surfaces to the action of water. Thus far roasted, the coffee grains are friable and of a light chesnut color, and their loss is not more than 18 per cent.; but if the operation has been continued until the berries are brown, there will be a carbonization of the chlorogenic acid, and a decomposition of the soluble principle of the coffee, and its useful products decreased 25 per cent.

The greatest advantage is derived from slightly roasted coffee, and the first infusion is always the most redolent of the delicious aroma of the more soluble essential oil. A second infusion, though equally dark colored, has the coarse flavor of the less soluble and less volatile essential oil.

There is no legumin in roasted coffee. It is this constituent that creates the ultimate fermentation of scalded raw coffee. The blackening of silver vessels in which coffee is boiled with alkalies, may also be attributed to this component. (*Rochleder.*) Among the numerous substitutes for coffee used by the poorer classes, are roasted rye, rice, and other grains. The dried, roasted, and ground root of the *Cichorium Intybus* (Wild Succory, Chicory), is used either as an adulteration of or a substitute for coffee. Pleischel states, from experience, that the infusion of roasted coffee is improved in taste and concentration, by an addition to the boiling water, just before pouring it over the ground coffee, of 5 grains carbonate of soda to every ounce. (?)

The *Essence of Coffee*, now coming into use, is a concentrated infusion of the roasted berry, obtained by displacement, and afterwards mixed with $5\frac{2}{3}$ of alcohol, or better, of strong, pure brandy.

Blume has recommended the leaves of the *Coffea Arabica* as a substitute for tea. It has long been used as such by the poorer people of Java and Sumatra. Prepared similarly to Chinese tea, the coffee leaves have an analogous appearance, taste, and odor.

COGNAC. *Tech.* A prefix to the most esteemed kind of BRANDY. The name originates from that of the town in France which is celebrated for the distillation of this kind of liquor.

COHESION. *Phys. Ger.* Zusammenhalt. The attraction of like particles of matter, Homogeneous Attraction, as distinguished from heterogeneous attraction or ADHESION; both acting, however, at insensible distances. A drop of water on a glass plate assumes a globular form, through the cohesive force of the particles of water, and adheres to the plate through the adhesive force between water and glass.

It is opposed by a repulsive force, probably identical with heat; and the relative quantity of these two forces determines the solid, liquid, and gaseous states of bodies. Cohesion predominates in solids; attraction and repulsion are nearly balanced in liquids; and cohesion is wholly wanting in gases, their particles being somewhat held together by gravitation.

The force of cohesion presents itself in so-

lids under various phenomena, giving rise to different physical properties, such as hardness, toughness, softness, brittleness. A body is *hard* when its particles resist separation, or sliding over each other, without altogether losing cohesive force, as the diamond, emory, &c. It is *tough* when the particles admit of sliding, and still retain cohesive force, as iron, copper, &c.; *soft* when they readily slide and separate from each other, as gypsum, fats; *brittle* when they separate easily, without sliding, as common salt.

Cohesion exerts an important influence on chemical operations; often diminishing and preventing the exertion of chemical forces. See **AFFINITY**, *modifying circumstances*, p. 64; **ADHESION**; **ANALYSIS**, *pulverization*.

COHOBATION. *Chem. Tech.* A term originally applied by Paracelsus to the repeated distillation of a liquid over the same substance. For example; in the distillation of essential oils, the water which runs over with the oleaginous portions of the plant, is reserved to *cohobate* with on the same material, in order to extract a new quantity of volatile matter. Being already more or less saturated, it is a more economical solvent than fresh water, and its use saves the loss which would inevitably accrue by a frequent change of water. In the distillation of plants whose volatile constituent is in minute per centage, *cohobation* is generally resorted to, but always over fresh material.

COLCHICUM AUTUMNALE. *Phar. Syn.* *Meadow Saffron.* The root, according to Pelletier and Caventou, is composed of

Fatty matter, { Olein,
Stearine,
Volatile acid,

Supergallate of *Veratrin*,
Yellow coloring matter,
Gum, starch, and inulin,
Lignin, and a minute portion of ashes.

Geiger and Hesse have latterly announced the presence, in the seeds, of a new powerfully poisonous principle, called **COLCHICIN**, of which $\frac{1}{16}$ of a grain is sufficient to kill a cat.

Colchicin. A colorless, crystallizable alkaloid, existing in the seeds, bulb, and flowers of the above plant, and perhaps also in the other species of the same genus. It is obtained by treating the pulverized seeds with alcohol acidulated by sulphuric acid, adding lime to the extract, filtering, saturating the clear liquor with sulphuric acid, and evaporating off the alcohol, decomposing the residue with carbonate of potassa, drying the precipitate, and then crystallizing it from an alcoholic solution. (*Liebig.*) It is in prisms or needles, of a bitter alkaline taste, and its aqueous solution precipitates the solutions of chloride of platinum, the infusion of nut-galls, and tincture of iodine. Its composition and atomic weight are unknown. Sulphuric acid colors it yellowish-brown, unchangeable into violet; and this test, together with its other characteristics, distinguishes it from veratrin, with which it was at first confounded. The salts of this base are mostly crystallizable, and readily soluble in water and alcohol.

COLCOTHAR. *Tech. Syn.* *Rouge, Crocus,*

Ferri Oxydum Rubrum. The sesquioxide of iron, prepared by roasting sulphate of iron (*green vitriol*), and hence its vulgar title of *Colcothar of vitriol*. By the action of fire, the water of crystallization and sulphuric acid are evolved, the iron being peroxidized at the expense of a portion of the latter, which then escapes as sulphurous acid.

COLD. Deficiency of **HEAT**.

COLLYRITE. **KOLLYRITE.**

COLOCYNTH. *Syn. Coloquintida, Bitter Apple, Bitter Cucumber.* The peeled fruit of the *Cucumis Colocynthis*, imported from Spain. "*Eis-lombhee*," supposed to be true colocynth, is, according to Dr. Royle, a distinct species, which he terms *Cucumis pseudo-Colocynthis*. The extractive matter of the pulp and seeds, combined with other purgatives, is the compound cathartic pill of our pharmacopœia. Besides other substances, it contains a peculiar principle, *Coloquintin*, bitter (*Colocynthin*), as will be shown by the annexed analyses.

Meissner's Analysis.

Bitter matter (<i>Colocynthin</i>).....	14.4
Extractive.....	10.0
Bitter fixed oil.....	4.2
Resin, insol. in ether.....	13.2
Gum.....	9.5
Bassorin.....	3.0
Gummy extract (obtained from the lig- neous fibre) by potassa.....	17.0
Vegetable jelly.....	0.6
Phosphate of lime and magnesia.....	5.7
Ligneous fibre.....	19.2
Water.....	5.0

Colocynth pulp, 101.8

Braccannot's Analysis.

Bitter matter (<i>Colocynthin</i>) with some resin.	41.4
Resin.....	4.3
Vegetable jelly (<i>pectin</i>).....	18.6
Azotic matter.....	21.4
Acetate of potassa.....	5.7
Deliquescent salt of potassa, not soluble in alcohol.....	7.1
Watery extract of colocynth,	98.5

Colocynthin. *Syn. Coloquintin bitter.* The active principle of the colocynth, in the form of a yellow-brown, bitter, resinoid matter, obtained by evaporating an alcoholic tincture of the watery extract of the pulpy part of the fruit, and precipitating the colocynthin, free from acetate of potassa, by cold water. It is soluble in water, alcohol, and ether, and is precipitated from its aqueous solution by chlorine, and many of the metallic salts, (protosulphate of iron and sulphate of copper, &c.) Potassa, lime, and barytes water occasion no precipitate. The physiological effects of limited doses are salutary in some diseases, but in excessive quantity it is dangerously poisonous.

COLOGNE WATER. *Syn. Fr. Eau de Cologne. Ger. Kölnischeswasser.* Used as a perfume, and is a solution of odorant essential oils in alcohol. To improve the scent, the disagreeable flavor of the alcohol is removed by distilling the mixture in a water-bath. In this way the unpleasant smelling ingredient of the alcohol, called *fousel* oil, is separated,

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and remains in the alembic, its boiling point being 269°, or much above that of water and alcohol. Annexed are some of the most valuable recipes for this much esteemed perfume.

Durockereau's Formula.

To 7 quarts of tasteless alcohol, add of

Essence of Portugal.....	dr. 11
“ Bergamot.....	dr. 13
“ Lemon.....	oz. 1
“ Neroli.....	dr. 10
“ Rosemary.....	oz. 1
“ Lavender.....	oz. 1
Water of Roses.....	dr. 14
“ Jessamin.....	dr. 13
“ Orange flowers.....	dr. 15

Mix the whole together, and after 24 hours' delay, distil over a water-bath. This is of 30 to 33° B. strength, and is of an agreeable aroma.

Crozet's Eau de Cologne concentrée.

Essence of Portugal.....	dr. 12
“ Bergamot.....	dr. 12
“ Cedrat.....	oz. 1
“ Lemon.....	oz. 1
“ Neroli.....	dr. 12
“ Rosemary.....	oz. 2
“ Lavender.....	oz. 2
“ Benzoin.....	dr. 2

Mix the whole together, with ten times its volume of good spirits of wine, and distil. The product which comes over, after being redistilled, is of an exquisite and powerful odor. For other recipes, see *Celnart & Morfit* on Perfumery.

COLOPHONITE. *Min.* See GARNET.

COLOPHONY. *Chem. Syn.* Rosin, Arcañson. From *Κολωνία*, the name of the city where it originated. When the resinous juice of the *Pinus Sylvestris*, and other varieties of pine, is distilled, the volatile spirits of terpentine passes over, and the colophony remains in the retort. Though differing entirely in composition from fats, it is partially substituted therefor in the manufacture of yellow soap. Rosin contains no glycerin, nor any equivalent for that substance, but consists, says Unverdorben, of two different resins, called the sylvic and pinic acids, separable from each other by cold alcohol, of sp. grav. 0.867, which dissolves the alpha resin (pinic acid), so termed, and leaves the beta resin, or sylvic acid. The formula of pinic acid is $C_{40}H_{60}O_4$, which is changed into $C_{40}H_{30}O_8$, or oxy-pinic acid, when an alcoholic solution of alpha resin is exposed to the air. The sylvic acid is readily soluble in absolute alcohol, ether, the fixed and volatile oils; melts at 305.5°, and consists, according to Trommsdorff, of $C_{20}H_{30}O_2$. The pinates of soda, potassa, and ammonia, as an exception to those of other bases, are soluble in water, whilst the corresponding sylvates, slightly deficient in this property, are readily taken up by anhydrous alcohol and ether. The formation of yellow soap from resin is due to a direct combination of its acids with the alkali employed. Sylvic acid, unlike the pinic, is crystallizable, and forms quadrilateral prisms with a rhombic base, but in other properties the two are not dissimilar. By distillation, the pinic acid is converted into Colopholic acid; and as there is usually a minute

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portion already formed in colophony, it has been styled by Berzelius the *gamma resin*.

As the two first-named acids are colorless, the dark hue of resin is owing to the action of the fire.

Pinaric acid, isomeric with the two first-named acids, and found in the terpentine of the *Pinus Maritimus*, crystallizes in small prisms, which by fusion become modified, and soluble in alcohol. (*Laurent*.)

Colopholic acid is distinguished from the pinic and sylvic acids by its brown color, greater affinity for bases, and lesser solubility in alcohol, of 67 per cent. Its salts resemble the pinates. (*Liebig*.)

Resinone, $C_{25}H_{46}O$, and Résinone, $C_{10}H_{18}O$, are two bodies obtained by Fremy, from the distillation of resin with lime.

A solution of colophony in pure potassa ley is used as a substitute for gelatin in sizing paper. See RESIN.

COLORING MATTERS. *Tech.* They may be classed together with reference to their application in the arts, but, chemically speaking, are of very different composition and properties. For the action of oxygen on some vegetable colors, see *Chem. Gaz.* xi., 328, &c. See INDIGO, Madder, QUERCITRON.

COLORIN. See Madder.

COLUMBIN. See CALUMBIN.

COLUMBITE. *Min. Syn.* Prismatic Tantalum ore; Tantalit. Cryst. system, Right Rhombic in part; combinations are vertical and horizontal prisms, terminal planes of all axes, and the octohedron; cleaves parallel with lateral terminal planes; occurs also massive with granular structure. $H. = 5-6$. $G. = 5.9-6.1$. Black; lustre submetallic; opaque; streak dark-brown; brittle; fracture subconchoidal, uneven. The blowpipe reaction of various columbites is different; borax and mic. salt either give the reaction of iron, or of the same with tungsten; soda may exhibit on platinum the presence of manganese, on charcoal of tin. It is easily decomposed by bisulphate of potassa. The per centage of columbic acid or oxide varies from 66 to 89 per cent. The discovery by H. Rose of a new metal, Niobium, as well as of a second, Pelopium, in some columbites, will reconcile differences which have been observed in their physical and chemical characters. The Finland columbite contains mainly columbic acid, and its formula is FeO, Ta_2O_3 . The columbites of Bavaria and Connecticut contain columbic and niobic acids. See COLUMBIUM. Columbite occurs at Broddbo, Finbo, Kimito; Tamela in Finland; Bodenmais, Bavaria; in the United States, at Middletown and Haddam, in Connecticut; Chesterfield and Beverly, Mass.; Acworth, N. H. A single crystal from Middletown weighed 14 lb.

COLUMBIUM. *Chem. Syn.* Tantalum. *Ger.* Tantal. *Fr.* Tantale. First observed in 1801, by Mr. Hatchett, in a black mineral in the British Museum, supposed to have come from Connecticut, U. S., and hence named Columbium. Found by Ekeberg, in 1802, in two Swedish minerals, tantalite and tyrotantalite. Tantalum was studied by Berzelius; and Columbium was found by Dr. Wollaston, in 1809,

to be the same metal. It occurs also in Euxenite, Fergusonite, Pyrochlor, &c. H. Rose has since found two other metals in the columbites, Pelopium and Niobium. Some of the characters ascribed to compounds of columbium are due to their presence, although the former descriptions by Berzelius are more correct, being based on the columbic acid derived from the tantalite of Finland, which Rose finds to be nearly free from the two new metals.

Berzelius obtained tantalum, by decomposing the double fluoride of columbium and potassium by potassium. A black powder, which may be washed and dried, and assumes an iron-gray metallic lustre under the burnisher. It takes fire in air under a red heat, and burns with much vivacity, to columbic acid. No acid has a sensible action upon columbium, except hydrofluoric. It combines with oxygen in two proportions, forming columbic oxide and acid. Eq. 184.9 or 2307.43 ?

1. *Columbic oxide.* Columbous acid. Obtained by exposing the acid in a charcoal crucible to the heat of a blast-furnace for an hour. The external film is metallic columbium; the mass is columbic oxide. Dark-gray; so hard as to scratch glass; soluble in no acid; heated to low redness in air, it burns slowly, and is partly converted into columbic acid. Form. TaO_2 .

2. *Columbic acid.* Columbium, in this state, exists in most of its minerals, with oxides of iron and manganese in columbite, with yttria in yttriotantalite. Obtained by fusing the mineral with carbonate of potassa, and decomposing the columbate of potassa formed by an acid, and also by fusion with bisulphate of potassa. A white powder, which reddens litmus; when heated, it parts with its water, and loses the latter property. Sp. gr. of the ignited acid, 6.5; it is then attacked by alkalies only. Columbic acid dissolves by fusion in bisulphate of potassa, and when hydrated in binoxalate of potassa in the humid way; soluble, in small quantity, in concentrated sulphuric acid, but precipitated from that solution by water. Form. TaO_3 .

3. *Sulphocolumbic acid.* Prepared by exposing columbic acid to a bright red heat, in a porcelain tube, and passing over it bisulphuret of carbon; a gray, pulverulent matter, resembling plumbago. It is a good conductor of electricity. Form. TaS_3 .

4. *Chloride of columbium*, TaCl_3 , obtained by heating columbium in chlorine, is, in the state of vapor, a yellow gas resembling chlorine; condensing into a white powder, with a shade of yellow.

5. *Fluorides.* Hydrated columbic acid dissolves in fluohydric acid, and by evaporation at a low temperature, yields crystals of fluohydrate of fluoride of columbium, which by heating becomes fluoride of columbium, TaF_3 . Double salts, crystalline, are formed by the caustic alkalies with the fluohydric solution. Form. of the potassa salt, 2 KF, TaF_3 .

6. *Columbates.* Formed by fusing columbic acid with caustic or carbonated potassa or soda. Soluble in a large quantity of water; the soda salt decomposing by boiling, or carbonic

acid, into an insoluble bicolumbate. The columbate of ammonia produces insoluble columbates in solutions of earths and other metallic oxides.

Columbium forms a more or less fusible alloy with iron.

COMBINING WEIGHTS. *Chem. Syn.* Atomic weights, Equivalents. *Ger. Mischungsgewichte.* The proportion by weight in which bodies combine; the numbers representing which become fixed, by reference to one body as unity. The two series of combining weights in use are those of the hydrogen and oxygen scales; the former being called 1, and the latter 100. These fixed numbers represent what is assumed to be one equivalent of each element. They are variously determined, the starting point being water. See *AFFINITY*, p. 52. Since water is found to consist of 88.9 per cent. oxygen, and 11.1 per cent. hydrogen, these numbers are in the ratio of 8 to 1; whence, on the hydrogen scale, the combining weight of one equivalent of oxygen is 8, of hydrogen 1; and on the oxygen scale, that of oxygen ≈ 100 , and of hydrogen 12.5. Where bodies unite in the gaseous form, it is easy to determine their combining weights, because we can measure the volumes of each element. Thus analysis proves that chlorohydric acid gas is composed of equal bulks or volumes of each element, hydrogen and chlorine, which are assumed to represent equivalents or atoms. By weight, it is composed of 97.26 per cent. chlorine, and 2.74 per cent. hydrogen; which, on the preceding assumption, represent the proportion by weight existing between an equal number of the equivalents of the two elements. Hence 2.74 per ct. hydr. : 97.26 per ct. chlor. :: 1 : 35.47 = combining weight of chlorine on the hydrogen scale; or :: 12.5 : 442.64 = its combining weight on the oxygen scale.

In a similar manner the combining weight of nitrogen may be determined from an analysis of the compounds of nitrogen and oxygen, such as the nitrous and nitric oxides.

If, however, one or both of the elements be solid, the determination of the combining weight is more dependent on assumption, although it is certain that the true combining weight stands in some simple ratio to the number obtained. Thus there are three compounds of carbon with oxygen, carbonic oxide, oxalic acid, and carbonic acid, in which the proportion of oxygen is 1, $1\frac{1}{2}$, 2, for the same quantity of carbon. Carbonic oxide is proved to consist of 42.86 per cent. carbon and 57.14 per cent. oxygen. Now if we assume that it consists of one equivalent of each element, then 57.14 : 42.86 :: 8 = comb. weight of oxygen : 6 = comb. weight of one equiv. of carbon. But if we assume that it consists of 1 equiv. of oxygen and 2 equivs. of carbon, then the number 6 obtained represents the combining weight of 2 equivs. of carbon, in which assumption the combining weight of carbon would be 3. But the former supposition is generally taken, so that one equiv. of carbon is represented by 6. It is, however, certain that it is a multiple or submultiple of 6.

The combining weights of the metals are

deduced from the relative proportion between the oxygen and metal in the strong base, that is, in that base or oxide which has the strongest affinity for acids to form salts, in which oxide it is assumed that there is one equiv. each of metal and oxygen. In the 2 oxides of iron, the relation between the oxygen is $1:1\frac{1}{2}$, and since, by the analysis of peroxide, there is 69.34 per cent. iron and 30.66 per cent. oxygen, the proportion $30.66:69.34::12=1\frac{1}{2}$ equivs. of oxygen : 27.14 = one equiv. of iron.

By means of **ISOMORPHISM**, the number of equivs. in an acid or oxide may be determined, when the number of equivs. of any one of the isomorphous bodies is determined. Having determined that the protoxide of iron or black oxide of copper consists of one equiv. each of metal and oxygen, then we have oxides isomorphous with them, each consisting of one equivalent of metal and oxygen, whence their combining weights may be determined from an analysis of their compounds. Thus we have the number of equivs. of the black oxide of copper, of the protoxides of iron, manganese, cobalt, nickel, zinc, and cadmium, and of magnesia and lime; and by the **DIMORPHISM** of lime, we have also the equivs. of baryta, strontia, and oxide of lead. On the same ground, the equivs. of sulphuric, selenic, telluric, chromic, and manganic acids, may be determined. Hence, by determining the number of equivs. in one of each of these two isomorphous groups, we determine them in the oxides of twelve elements; and when we know the number of equivalents, their combining weights are determined from the per centage composition of their compounds. See **EQUIVALENTS**, for the combining weights of all the elements. See **COMBUSTION**, for the heat resulting from combination.

COMBUSTIBLE. *Chem. Tech.* In its limited and more usual sense, it is a body capable of combining with the oxygen of the air, evolving at the same time light and heat; and the act of union is termed

COMBUSTION. *Chem. Tech.* Two kinds may be added, ordinary fire, and low or slow combustion. Ordinary combustion is that in which a body unites with the oxygen of the air, and evolves heat and light. Carbon, hydrogen, sulphur, phosphorus, and metals, are combustible; and since the two first enter largely into organic bodies, these are all combustible. The resulting products of combustion are oxides, which are either bases or acids. If the combustible be gaseous or vaporizable, it burns with flame, sulphur, hydrogen, phosphorus; if not volatile, it burns without flame, pure carbon, anthracite, iron, and some other metals. Common combustion is resorted to for the production of heat, and hence wood and coal, containing chiefly carbon and hydrogen, are the combustibles employed, under the common name of **FUEL**. Matter is not annihilated by combustion, for the products resulting from burning fuel are carbonic acid and water, which, when caught and weighed, are found to equal the weight of fuel together with the oxygen derived from the air, less a small amount of ashes, &c. If the air supplying combustion be insufficient, car-

bonic oxide is produced instead of carbonic acid, and being itself combustible, burns with a blue flame at the top of a fire, if the air have access; hence, on opening the upper door of a coal-stove, the entrance of air causes a burst of flame over the upper surface of the coal. Carbonic acid is the chief product of combustion with anthracite and charcoal, and hence, when they are burned in a close room without free ventilation, the accumulation of the invisible gas often produces suffocation.

Low combustion is the more gradual union of oxygen with combustibles, attended with the evolution of heat, and sometimes of light, but where the heat is less and the resulting products different from ordinary combustion. Thus nitric oxide combines in the cold with oxygen, forming the red fumes of peroxide of nitrogen. Phosphorus is luminous in the dark at common temperatures, and emits an odor due to light white vapors, phosphorous acid, PO_3 , but when heated in the air it burns brilliantly, giving off dense white fumes of phosphoric acid, PO_5 . In the former low combustion heat is evolved, for if several pieces of phosphorus be laid together, the sum of the heat, by their slow oxidation, causes them to burst out into a flame. The effects of low combustion are striking among organic bodies. Fats become rancid in the air by oxidation, and apparently evolve no heat, but if their surface be extended, as when a mass of cotton is imbued with oil, the sum of the heat is such as often to induce conflagration, as in cotton-mills. The oxidation of iron pyrites in coal has given rise to its spontaneous combustion. The light evolved by decaying fish and wood is probably due to the same cause. Carbonic acid and water are the products of ordinary combustion of wood or organic matter; thus alcohol, which is composed of $C_4H_6O_2$, takes up O_{12} , by inflammation, to form 4 CO_2 and 6 HO , but by slow combustion it first takes up O_2 , forming 2 eq. water, 2 HO , and a liquid called aldehyde, $C_4H_4O_2$; and by its farther oxidation, aldehyde takes up two more of oxygen, forming acetic acid, $C_4H_4O_4$. In the quick vinegar process, alcoholic liquors are thus oxidized into acetic acid, producing heat sufficient to raise the temperature of the apartment. For other applications of low combustion, see **APHLOGISTIC LAMP**, **EREMACAUSSIS**.

"The determination of the *quantity of heat* produced during the combustion of a given quantity of combustible substance is a problem of great importance in the arts, as on it depends the economic value of all varieties of fuel. The plan generally followed has been to burn the substances by means of the smallest quantity of air which is sufficient, in a vessel surrounded, as far as possible, with water. If it be found that the burning of a pound of wood heats 37 pounds of water from 32° to 212° , no idea can be thereby formed of the quantity of heat evolved; but if, on another trial, it be found that the burning of a pound of charcoal raises the temperature of 74 pounds of water through the same range, it follows that the charcoal had double the caloric power of the wood. True relative numbers can thus be obtained, although they have

independently no positive signification. The results obtained in this manner have been exceedingly discordant; but, by the late researches of Despretz and of Bull, which appear to have been conducted with more attention to accuracy than former ones, a very

1 lb. of oxygen, uniting with hydrogen,	heats from 32° to 212°, 29½ lbs of water.
“ “ “ charcoal,	“ “ 29 “
“ “ “ alcohol,	“ “ 28 “
“ “ “ ether,	“ “ 28½ “

“This rule, however, must be liable to some very curious changes; for one pound of oxygen, in combining with iron, could heat, by Despretz’s experiments, 53 pounds of water, or almost exactly twice as much as in the former list; and with tin and zinc the same double proportion held. With phosphorus a singular peculiarity was observed, which, when the subject comes to be more fully studied, may throw some light upon the former differences. When phosphorus burns slowly, so as to form phosphorous acid, it heats, in combining with a pound of oxygen, 28 pounds of water; but when it burns brilliantly and forms phosphoric acid, the heat evolved is doubled, and becomes the same as that produced with iron, tin, or zinc. As a suggestion, I would remark, that in the cases where the smaller proportion of heat is evolved, the products of combustion are all volatile, and where the larger proportion is produced, the products are fixed and solid; even in the case of phosphorus, when it combines, producing least heat, it forms a volatile product, but one which resists a full red heat

in the case where the combination has been complete.

“Hess has lately pointed out a relation between the amount of chemical action and the quantity of heat evolved, which may, when examined in a greater number of cases, lead to very important conclusions. He has found that sulphuric acid, in combining with any base, generates in all cases the same quantity of heat; the rise of temperature is, of course, greatest when the acid and base are both in an uncombined condition, as where vapor of anhydrous sulphuric acid produces, by contact with dry barytes, brilliant ignition; but, although the barytes generates, by contact with dilute sulphuric acid, much less heat, yet, if the two quantities evolved, first by mixing the strong acid with water, and then the dilute acid with the base, be added together, the sum appears, from a great number of experiments, to be constant; thus, diluting oil of vitriol with water, and neutralizing it so diluted, with ammonia, Hess found the heat in each case to be,

	With Ammonia.	With Water.	Sum.
Oil of vitriol.....	595.8.....		595.8
First dilution.....	518.9.....	77.8.....	596.7
Second dilution.....	480.5.....	116.7.....	597.2

Connecting these results with those of Despretz, just given, for the bodies which unite with oxygen, it would appear likely that the quantity of heat evolved in chemical combination may be connected with the equivalent number and the electrical condition of the substances by a definite law, which farther investigation may disclose.” (Kane.)

See HEAT, FLAME.

COMMON SALT. *Min. Syn.* Hexahedral Rock-salt; Rock-salt. *Ger.* Steinsalz. (See also Chloride of Sodium.) Cryst. system, Regular; combinations are cube, 8, 12, and 4 × 6-hedron. It also occurs massive with fibrous or granular structure. *H.* = 2; *G.* = 2.257. White, sometimes yellowish, reddish, rarely blue; lustre vitreous; transparent, translucent; taste pure saline. Form. NaCl.

Localities, &c.—Common salt usually occurs in extensive but irregular beds, in rocks of various ages, associated with gypsum, polyhalite, clay, sand-stone, and calcareous spar; also dissolved, and forming salt springs.

In Europe it usually occurs in the new red sandstone, or associated with red marl, but it is not confined to these rocks. At Durham, Northumberland, and Leicestershire, England, salt springs arise from the carboniferous series; in the Alps, some salt works are supplied from oolitic rocks; the famous mines of Carbona and Wieliczka, are referred, the former to the green sand formation, and the

latter to tertiary rocks. Salt springs also occur in volcanic regions. In the United States the salt brines mostly come from the sandstones below the coal. It also occurs as efflorescences over the dry prairies of the Rocky Mountains and California; and in most desert or semi-desert regions there are frequent salt lakes.

The principal mines of Europe are at Wieliczka, in Poland; those of the Salzkammergat, in Upper Austria; Ischil, Hallein, in Salzburg; Hall, in the Tyrol; Bex, in Switzerland; and Northwich, in Cheshire. At the latter place it occurs in a basin-shaped deposit, and is arranged in spheroidal masses, from 5 to 8 feet in diameter, which are composed of concentric coats, and present polygonal figures. It is but little contaminated with impurities, and is prepared for use by merely crushing it between iron rollers.

It also occurs in the sandy regions of Africa and Persia, where it has resulted from the evaporation of salt water. A beautiful pure white variety now fills Lake Mareotis, near Alexandria, Egypt; at a distance it resembles a bank of snow.

In the United States it has been found forming large beds with gypsum, in Virginia, Washington county, 18 miles from Abingdon, and in the Salmon river mountains of Oregon. Brine springs are very numerous in the Middle and Western States. The most famous of

these springs are at Salina, in N. Y., and in the Kenawha and Muskingum Valleys, Ohio, and in Kentucky.

COMPOUND RADICAL. *Chem.* A name given to a supposed body, composed of two or more elements, which acts as a simple body or element in many of its combinations. Thus ammonia, NH_3 , with one equivalent of water, HO , acts precisely like potassa and soda, combining with acids to salts of the same crystalline form with the corresponding salts of potassa, in which case its formula is NH_4O . Now since it thus acts like the oxide of a metal, it may be viewed as such, and the metallic base or radical of the oxide has the composition NH_4 , called ammonium. Whether viewed as a metal or not, there is present a compound body, capable of combining with oxygen, sulphur, and chlorine, and of forming a large class of salts. Again, from prussian blue, a salt containing potassa may be prepared, from which various other salts may be produced by single or double decomposition, in all which some analogy is observed with the corresponding chlorides. In most of these we find the composition $\text{M}, \text{C}_2\text{N}$, like a metallic chloride, MCl ; and even an acid, the prussic, $\text{H}, \text{C}_2\text{N}$, like the chlorohydric, HCl ; the compound body C_2N acting precisely like chlorine. This compound body, or radical, obtained in a separate state, is called cyanogen, and its compounds cyanides.

Ether obtained from alcohol, by oil of vitriol, has the composition $\text{C}_4\text{H}_5\text{O}$, in which the O may be replaced by sulphur, chlorine, &c., or the oxide unites with acids to form a large class of salts. C_4H_5 , called ethyl, is the compound radical of this series.

A large number of such compound radicals are assumed to form compounds like simple bodies, such as Benzil, Salicyl, Methyl, Formyl, Acetyl, Margaryl, &c., but it is to be feared that the doctrine, however plausible, may be carried too far. The attempt to subject the complex bodies of organic nature to the apparently more simple laws of union of inorganic bodies, first led to the theory of compound radicals, and, by a natural reaction, the peculiarities thus developed in organic bodies have been transferred to some of the inorganic combinations. See **SALTS**.

CONCENTRATION. *Chem. Tech.* A process producing an increase of the density of liquids. In a wider signification, it is a decrease of the compass of bodies or particles of liquids. Thus in the *strengthening* of solutions whose substance is less volatile than the menstrua in which it is dissolved, the more fluid portion is entirely or partially dissipated by evaporation. Hence the term concentrated extract applies to the inspissated juice of any substance, and that of concentrated solution to a liquid saturated, or nearly so, with soluble material. The concentration of alcoholic and ethereal solutions is effected by distillation, because the worth of the volatile solvent more than compensates for the cost of saving it. Concentration of liquids in open pans is practised only in those instances where the fixed ingredient of a solution is the sole product of value. Thus the dilute sulphuric acid from

the lead chambers is first concentrated in open leaden pans, and then farther concentrated in a platinum still. Some aqueous liquids may likewise be concentrated by freezing, in which water chiefly separates as ice; for example, solutions of salt, vinegar.

CONCRETIONS. *Chem.* Solid matters, earthy and organic, are found in various parts of the animal system, the results of deranged action. Geiger's analysis of one from the nose, gave 23.3 animal matter, mucus, albumen, &c., + 46.7 phosphate of lime, + 21.7 carbonate of lime, + 8.0 carbonate of magnesia, = 99.7. Petroz and Robinet found one from the pericardium, composed of 24.3 gelatinous and albuminous matter, + 65.3 basic phosphate of lime, + 6.5 carbonate of magnesia, + 4.0 sulphates of soda and lime, = 100.1. Wurzer's analysis of one from the eye of a blind person, gave 11.9 fat, + 5.9 common salt, &c., + mucus 20.3, + phosphate of lime 47.3, + carbonate of lime 8.4, + carbonate of magnesia 1.1, + oxide of iron 0.9, + water 3.0, = 98.8. Brandes found in one from a woman of 75 years of age, animal matter 4.52, + phosphate of lime 79.56, + carbonate of lime 6.41, common salt 0.58, + water 8.93, = 100. (*Berzelius*, ix. 721.) See **BILE**, **BEZOAR**, **LITHOFELLINIC ACID**, **URINARY CONCRETIONS**.

CONDENSATION. *Chem. Phys.* The closer proximity of the particles of any body produced by compression or cooling, thereby increasing its specific gravity. As heat expands bodies, so its abstraction condenses them, and makes them occupy a smaller space. Solids, liquids, and gases may be condensed by compression, although liquids and solids are far less compressible than gases, and often in such a trifling degree as to render it difficult of determination. See **WATER**. The difference in the sp. gr. of solids and liquids at lower, compared with ordinary temperatures, renders their condensation evident. Gases are frequently so far condensed, by the union of pressure and cold, as to bring them into a liquid state (chlorine, sulphurous and carbonic acids, &c.), when, by their rapid evaporation and the consequent absorption of heat, the remaining portion may be rendered solid, as carbonic acid. Faraday's method is to introduce the materials for generating a gas into one end of a syphon tube, and after sealing it hermetically, to apply heat to the same end and artificial cold to the other, in the latter of which the gas condenses.

Condensation is also applied to the passage of a vapor into the liquid or solid state in the process of distillation or sublimation. Thus mercury passes over in a retort as a vapor, and condenses as a liquid in the recipient; sulphur collects or condenses as a crystalline powder, called flowers of sulphur.

For various forms of condensers see under **REFRIGERANT**, **ALCOHOL**, referring to Pl. II., figs. 5, 6, 7, 8.

CONDIMENTS. *Tech.* Under this head is comprised a class of articles used as seasoning for food, and in some few instances to assist its digestion. The *saucers*, such as *ketchup* and the like, are compounded of two or more condiments so as to improve the taste

and flavor of one or both or all by the mixture. Salt is the only saline condiment, and being an essential ingredient of blood, it serves the double purpose of gratifying the palate and repairing the daily loss of saline products secreted by the tears and bile. Of the *acidulated* condiments, vinegar is the most grateful. The aromatic condiments, consisting of the spices and savory herbs, are useful only for flavoring. The oily condiments (butter and oil), and the saccharine (sugar, honey, and molasses), are nutritive as well as pleasant to the taste.

CONDURRITE. *Min.* Massive, compact, earthy; soft; $G.=5.2$; brownish black; fracture flat conchoidal. In a closed tube it yields water and arsenious acid; on charcoal it gives the reaction of copper and arsenic. Form. $6CuO, AsO_3 + 4HO (?)$. *Local.* Condurra Mine, Cornwall.

CONGELATION. The freezing of water.

CONGLOMERATE. *Geol.* A formation consisting of fragments of rocks, either rolled or angular, cemented by carbonate of lime, silica, oxide of iron, or clay. When the fragments are rolled, it is often termed Pudding-stone; when angular, Breccia.

Conglomerates are variously named, according to the predominating character of their composing fragments; as the siliceous, calcareous, &c.

CONICIN, CONIIN. See CONIUM.

CONITE. See BITTER SPAR.

CONIUM MACULATUM. Syn. Spotted hemlock (*Cicuta*).

The analysis of Schrader proves its striking similarity in composition to white cabbage, (*Brassica oleracea*.)

Extractive	2.73
Gummy extractive	3.82
Resin	0.15
Vegetable albumen.....	0.31
Green fecula.....	0.80
Water, salts of lime, potash, iron, manganese with sulphuric, nitric, hydrochloric, and phosphoric acids.....	92.49

100.00

A subsequent examination by Brandes develops two additional ingredients, an acrid volatile oil, and a peculiar basic principle *Conicin*, and also a problematical acid, the *conic*.

Conicin. Syn. Conia, Cicutine, Concein. A poisonous liquid alkaloid of spec. grav. 0.89, procured by distilling the seeds of hemlock with potassa solution. Its equiv. is 108.7, and its formula $C_{12}H_{14}NO$. It is more soluble in cold than in hot water and the alkaline solutions, and with alcohol mixes in all proportions, forming a compound more soluble in water than the pure conicin. It distils unaltered at 370° , and when anhydrous loses its alkaline properties. Nitric acid colors it blood red, and exposure to air decomposes it into ammonia and resinous matter devoid of poisonous properties. The salts which it forms with the acids are soluble in water and alcohol, but

insoluble in ether, and difficultly crystallizable.

CONTACT. *Chem.* Another name for the phenomena called elsewhere

CATALYSIS and PRESENCE. Although many such phenomena are thrown together, platinum seems to act in the most surprising manner, especially in its finely divided or spongy state. "It is an action of the metallic surface, which must be perfectly clean, and is retarded or altogether prevented by the presence of oily vapors and many other combustible gases, which soil the metallic surface. Faraday is disposed to refer the action to an adhesive attraction of the gases for the metal, under the influence of which they are condensed and their particles approximated within the sphere of their mutual attraction, so as to combine. This opinion is favoured by the circumstance that the property is not peculiar to platinum, but appears also in other metals, in charcoal, pounded glass, and all other solid bodies; although all of them, except the metals, act only when their temperature is above the boiling point of mercury. But on the other hand, at low temperatures, the property appears to be confined to a few metals only which resemble platinum in their chemical characters, namely in having little or no disposition to combine with oxygen gas, and in not undergoing oxidation in the air. The action of platinum may, therefore, be connected with its chemical properties, though in a way which is quite unknown to us. The same metal disposes carbonic oxide gas to combine with oxygen, but much more slowly than hydrogen; and it is remarkable that if the most minute quantity of carbonic oxide be mixed with hydrogen, the oxidation of the latter under the influence of the platinum is arrested, and not resumed till after the carbonic oxide has been slowly oxidated and consumed, which thus takes the precedence of the hydrogen in combining with oxygen. This extraordinary interference of a minute quantity of carbonic oxide gas, which cannot from its nature be supposed to soil the surface of the platinum like a liquefiable vapour, seems to point to a chemical, perhaps to an electrical explanation of the action of the platinum, rather than to the adhesive attraction of the metal. The oxidation of alcohol at the temperature of the air, and also at a low red heat, is promoted in the same manner by contact with platinum." *Graham.*

CONVOLVULIN. *Chem.* An alkaloid found by Marquant in the root of the *Convolvulus Scammonia*, and supposed to exist also in jalap. It crystallizes in groups of needles, is slightly alkaline, neutralizes the acids, and is precipitated from its aqueous solution by tincture of nut-galls.

COPAIVA BALSAM. *Phar. and Ch.* Syn. *Copaiba*. The clear liquid resinous exudation of the different species of *Copaifera*. Spec. grav. from 0.95 to 0.96. Thickens on exposure. Insoluble in water, but soluble in alcohol, ether, and the oils. The action of alkalies converts it into a kind of soap, which is insoluble in water.

COPAL.

Gerber's analysis of copaiva balsam gave

	Fresh Balsam.	Old Balsam.
Volatile oil	41.00	31.70
Yellow hard resin, <i>copaivic acid</i> ..	51.38	53.68
Brown soft resin.....	2.18	11.15
Water and loss.....	5.44	4.10
	100.00	100.63

Oil of Copaiva ($C_{10}H_8$) obtained by distillation, is aromatic and colorless, and polarizes a little to the left. Its spec. grav. when free from water is 0.878, and boiling point 473° F. Absolute alcohol dissolves 2-5ths of its weight, but 21 parts of that of ordinary strength are required to take up one part. The crystallizable camphor which it forms with HCl acid is isomeric with the same compound from oil of lemon, and the action of this acid allows the supposition that it consists of two isomeric oils, as there is also an oily compound simultaneously produced. Ether free of alcohol mixes with balsam in all proportions. Iodine dissolves in it, and imparts a red color to the solution. Chlorine and sulphuric acid act similarly as upon essence of turpentine. Fuming nitric acid after violent action transforms it into a crystalline body, which passes through the shades of yellow and blue finally to green. Potassium kept in this oil remains unaltered. The residue remaining in the retort after the separation of the oil, and called *copaiva resin*, $C_{45}H_{35}O_4$ (Rose), is found sometimes in crystals upon the sides of the vessels in which the balsam is packed. Schmetzer obtains it in crystals directly from a solution of 9 parts of balsam in 2 parts of ammonia. It consists of two resins, the amber colored *copaivic acid*, (Syn. *Copahuic* and *Copaibic*), and a *viscid resinous brown matter*, separable by alcohol in which the latter is insoluble. *Copaivic acid* is brittle, crystallizable, soluble in ether, alcohol, and the oils, and decomposed by sulphuric and nitric acids, the latter transforming it into an azotized insoluble and a non-azotized soluble matter. It forms salts with the bases, and is isomeric ($C_{40}H_{32}O_4$) with pinic acid. The *copaivate* of silver is crystallizable. The *viscid resin* is doubtless the acid resin in an altered state, but has scarcely any affinity for the bases. Anhydrous alcohol and ether, as well as the volatile and fixed oils, dissolve it readily.

Ammonia is no longer a sufficient test of the genuineness of balsam, for the clear solution which it forms in union with it is not at all affected by the presence of even one-sixth of oil of juniper; and again, moreover, according to J. E. Simon, there are some perfectly pure balsams which will not bear this test. A drop of true balsam on white paper, should, upon being heated, appear transparent, for if it is surrounded by an oily areola, Chevallier says, it is adulterated with some fat oil.

COPAL. *Tech. and Chem. Syn. Gum Copal.* A resin of spec. grav. 1.04 to 1.13 which spontaneously exudes from the *Rhus Copallinum* and the *Eleocarpus copaliferus* of the East Indies. Unverdorben and Filhol (Ch. Gaz. vol. i. p.

COPPER.

285) have constituted it of five distinct resins slightly variable in properties. Alcohol of 0.895 only dissolves a portion, but it is readily taken up by a mixture of equal parts of *Caoutchicine* and alcohol of 0.825. Boiling alcohol or any hot spirits of turpentine when poured upon fused copal effects its complete solution, but treated at once with too large a quantity coagulates instead of dissolving. Oils of turpentine, lavender, rosemary, and ether transform the resin into a swollen gelatinous mass, but do not dissolve it. Neither ammonia nor potassa cause its solution. Nitric acid in excess, by heat, decomposes the copal and converts it into a clear solution. Filhol asserts that those resins, richer in oxygen, are the most soluble, and that a transition of the insoluble resins into soluble ones may occur by oxidation in the atmosphere, and hence the complex nature of copal, which consists of several minor resins of differing solubility. Calcutta yellow copal is composed of carbon 80.29, hydrogen 10.57, oxygen 8.77. The *soluble* copal of Durosier, which alcohol and ether dissolve without residue, is Indian copal, which has been triturated with hot water to an impalpable powder, and kept exposed to the atmosphere. The finely comminuted copal, by oxidation at the usual temperature, becomes not only soluble but changed in constitution to carbon 71.34, hydrogen 9.22, oxygen 19.44. When acted upon by alcohol of various strengths, it is found to consist also of several resins, but one or two present in the original copal have been transformed by the change. The compound of soluble copal and potassa is immediately precipitated from its aqueous solution by an excess of alkali. The *epsilon* resin ($C_{40}H_{31}O_2$) forms no union with bases. The formula of the *alpha* resin is ($C_{40}H_{32}O_5$, probably) similar to that of the *beta* resin. The *gamma* resin ($C_{40}H_{31}O_3$), which is the most abundant component of copal, contains less oxygen than the last two. The *delta* resin is a white powder, but we are ignorant of its composition. A solution of copal in a hot mixture of linseed oil and the spirits of turpentine, is the varnish so largely used in the arts.

COPALITE. *Min. Syn.* Fossil copal, Highgate resin. One of the native resinous substances, resembling copal in its external characters, and found in the blue clay of Highgate Hill, near London. Form. $C_{40}H_{32}O$.

Another resin resembling copalite in appearance, from the walls of a trap-dyke in Northumberland, had the formula C_4H_3 . See BERENGELITE.

COPPER. *Chem. Tech. Syn. Lat.* Cuprum. *Ger.* Kupfer. *Fr.* Cuivre. *Alchem.* Venus. Copper has been known and used from the earliest times, both alone and alloyed with zinc and tin. Its name is derived from the island of Cyprus, whence it was largely obtained at an early period of Grecian history. It occurs abundantly in nature, as metal, sulphuret, arseniuret, oxide, carbonate, arseniate, phosphate, silicate, &c.; but it is chiefly obtained from sulphuret of iron and copper (copper pyrites), red oxide and carbonate, of which the pyritous copper furnishes $\frac{9}{10}$ of all the metal used in the arts. The whole quantity

of copper produced in the world is about 25,000 tons; of which Europe produces 18,000, and Cornwall, in England, 10,000 of the latter annually.

METALLURGIC TREATMENT OF COPPER ORES.

1. The carbonate and red oxide of copper found at Chessy, France, is prepared to a *schliech* of 27 pr. ct. richness, and smelted in a low blast-furnace, with the addition of 20 pr. ct. limestone, and 50 pr. ct. of the weight of ore of slag. The slags are chiefly silicate of alumina, lime, and protoxide of iron, and when they contain a little copper are again passed through the furnace with ore. The black copper obtained is then refined in a reverberatory or flame-furnace with a blast of air.

2. *Process at Swansea, England.* It consists of several successive roastings and fusions, terminating in the refining process, all performed in reverberatories. Pl. VI. fig. 9, is a vertical section of the roasting furnace; fig. 10 the ground plan. The hearth has an oval shape, and is covered with a flat arch. Its length is 17 feet, breadth 14, mean height 2 feet. *a* is the fire-door; *b* the grate; *c* the fire-bridge; *d* the chimney; *ee* working apertures on each side of the furnace; *ff* cast-iron hoppers; and *gg* openings in the arch, through which the ore is introduced; *h* the hearth-sole; and *ii* holes in it; *k* a vaulted space under the hearth.

Fig. 11 is a vertical section of the fusing furnace; Fig. 12, the ground plan. *a* is the fire-door; *b* the grate; *c* the fire-bridge; *d* the chimney; *e* the side openings; *f* the working-doors; *g* the running out hole; *h* iron spouts, to conduct the melted metal into pits filled with water. The melting furnace is much smaller (11 ft. by 8), but its firing hearth is considerably larger than in the roasting furnace.

a. The sorted, stamped, and washed ore, so mixed as to average $7\frac{1}{2}$ pr. ct. copper, is roasted in the furnace, figs. 9 and 10, until a considerable quantity of sulphur is expelled and much iron, &c., oxidized, when it is raked out through *i* into the arch *k*. It is then fused in the furnace, figs. 11 and 12, with the addition of rich slags of limestone, sand, fluor spar, according to the nature of the ore, and when a sufficient quantity has collected, it is run off by the tap *g*, through *h*, fig. 12, into water, which granulates it, and it is termed *coarse metal* or *matt*. The scoria, previously drawn out through the door, should not contain copper. Coarse metal contains about 33 pr. ct. copper, together with iron, sulphur, &c.

b. The copper-stone, or matt, is next roasted in the calciner, and again fused in the fusing furnace, refining slag being added. The *fine* or *blue metal* thus obtained contains 60 pr. ct. copper. The slag is chiefly silicate of protoxide of iron, but if it contain copper, is added to the first fusion of ore, or separated and smelted with coal.

c. The fine metal is roasted and melted as before, the *coarse copper* being run into pigs. The metal now contains 70–80 pr. ct. copper, and the scoria containing copper are added to the fusion under *b*. The coarse copper is then roasted and fused again. Latterly the last

operations have been condensed by running the fine metal into pigs, called *blue metal*, roasting these in a flame-furnace, where access of air is facilitated by openings in the fire-bridge, and fusing in the same furnace. It is covered with blisters, and hence termed *blistered copper*.

d. Refining or toughening. The metal from *c* being rather brittle, is toughened by heating the pigs in a refining furnace, slightly at first, to oxidize partially, then highly to fuse the metal. When fused, the slag is removed and charcoal strewed over the metal, which is stirred with a birch pole, during which the melted mass effervesces. Samples taken out from time to time indicate the finishing point of refining, by their lighter red color, silky appearance, and malleability. It is then ladled out, and cast into bars.

3. *Swedish Process.* The ores in a gangue of quartz or iron pyrites are mingled in due proportion, so as to average $2\frac{1}{2}$ pr. ct. copper, and after roasting, are fused in a low blast-furnace 7–10 ft. high (Suluschmelzen), yielding a *copper stone* containing about iron 60 + copper 10 + 25 sulphur, together with zinc, silica, &c. The slag contains about 45 silica and 55 bases, chiefly protoxide of iron. The copper stone is roasted 4 or 5 times in stalls, the heat of each roasting being increased, and then fused in a small blast-furnace, siliceous ore being added, its silica combining with the protoxide of iron and its sulphur facilitating the fusion of the metal, called raw copper, which contains 70–90 pr. ct. copper, with iron, and a little sulphur, zinc, &c. It is then refined on a hearth, a blast being urged over the surface of the metal. The whole loss of copper in the operations was found by trial to be 23.3 pr. ct.

4. Somewhat analogous to 3 is the process followed with the Mannsfeld copper-slate; a black slate containing copper pyrites, bitumen, cobalt, nickel, silver, &c., from which copper is first extracted, and silver from it.

a. Extraction of Copper. About 100 tons of the assorted slate, containing 1 to 3 pr. ct. copper, are calcined in a large heap, the bitumen and sulphur present assisting the combustion, and then fused in a blast-furnace, represented on Pl. VII. figs. 1 and 2, from 13 to 17 ft. high. Fig. 1 is a vertical section in the line A B, fig. 2. *a* is the shaft; *b* the bosh; *c* the twyer; *d* the hearth-stone; *ee* the lining of firebrick; *ff* and *g* the filling and casing; *hh* the taps for alternately running off slag and stone into the basins, *ii*. Fig. 2 is a horizontal section in the line E F, fig. 1. Fluor spar and rich slag are added to promote fusion and regain copper. The copper-stone run out contains 30–40 pr. ct. copper, and 1–2 ounces silver. It is roasted 3 times (Spurrost) in stalls, and again fused with the addition of slags, yielding fine metal (Spurstein) containing 50–60 pr. ct. copper, besides iron, sulphur, &c. The fine metal and thin-stone, roasted 6 times (Gaarrrost), are smelted and run out as *black copper* (Schwarzkupfer). The latter is at the bottom, thin-stone (Dünnstein) above it, and copper-slag at the top. The black copper contains 96 pr. ct. copper, or in 114 lbs., 110 lbs. copper and 6–9 ounces silver. Thin-

stone has the same composition as variegated-copper-ore.

b. When black copper contains 4 ounces or less of silver in 114 lbs., it is refined as copper, but if as much as 4½ ounces, the silver is extracted by lead or mercury.

By *lead*. The black copper is stamped, and passed through a low blast-furnace with lead, in the proportion of 3 copper to 10 or 11 lead, a process termed *Frischen*. The *frisch* pieces (24 inches diameter and 3 inches thick) are subjected to *liqutation* (*Saigern*) on a *frisch-hearth* (*Saigerheerd*), Pl. VII. fig. 3. It consists of 2 parallel walls, with ½ to 1 ft. space between, on which are laid 2 iron plates, *dd*, with an open slit between them. There are two walls at the sides, and a long wall, *b*, at the back, rising 2 ft. higher. *c* is an iron door, which may be raised or depressed by a pulley; *eee* an iron trough or channel into which the lead liquates and runs towards one end into a crucible. Six or eight *frisch* pieces are placed on the hearth, *a*, 6 inches apart, the interstices being filled with live coals, and black coal piled on above, when the door is let down. The lead flows down into the channel below, carrying the silver with it, and leaves a porous mass (*Kiehnstock*) on the hearth, consisting of 70 copper and 30 lead, with a little silver. The *kiehnstocks* are then heated in a furnace, resembling the *frisch-hearth*, to a higher heat (*Darren*), when more lead liquates and leaves the darrlings on the hearth, containing 70 to 90 pr. ct. copper, and 30 to 10 lead. The darrlings are then smelted on a low hearth, a blast of air urged over the surface to oxidize the lead, iron, and more or less copper, which flow off as slag. The copper thus made still contains lead, which unfits it for many operations, by injuring its malleability.

By *mercury*. The copper-stone is stall-roasted 3 times, stamped, and sifted, and roasted in a furnace to complete oxidation and partly form sulphates. It is then mixed with powdered limestone and salt moistened with water, dried, powdered, and heated, during which sulphuric acid expels muriatic acid, leaving sulphates of lime and soda, while the chloro-hydric acid unites with metallic oxides, forming chlorides, among others that of silver. Mercury is then added to the above, and black copper, made into a paste with water, the whole stirred for 18 hours, and after thinning with more water stirred again to collect the amalgam. The mercury amalgamates with silver, whose chlorine passes over to the copper. After removing all the amalgam, the residue is made into cakes with clay, and smelted for copper by admixture with slags and fluor spar.

By amalgamation more silver is obtained, and less copper, but the copper is of better quality than in the eliquation process. For the traces of lead remaining in the latter render the copper more brittle under the hammer.

Theory of the Copper Process. The ores contain iron and copper pyrites (the latter a compound of sulphuret of iron and copper). If they were now to be subjected to fusion, the consequence would be an imperfect slag, from

the want of oxides to unite with silica; hence the roasting of the ore, which expels a portion of sulphur as sulphurous acid, and leaves another portion as sulphuric to unite with the generated metallic oxides, chiefly as protosulphate of iron. But all the sulphur is not oxidized, in order to promote the fusibility of copper and iron in the next operation of smelting, and to afford the means of farther separating iron from copper. The roasted ore is next fused, during which silica unites with protoxide of iron (lime, alumina, &c.), while a portion of sulphuric acid is reduced to sulphur, which, with the remaining sulphur, form with iron and copper a copper pyrite, containing in the Swedish process an excess of iron, but in the English and Mannsfeld processes resembling the native mineral. The second roasting and fusion produces a similar slag of protosilicate of iron, and a copper-stone, fine metal in the English process, spur-stone of the Mannsfeld, analogous to variegated copper ore. The thin-stone of the latter process has the same composition. The third roasting and smelting act similarly but produce a metal consisting of copper enclosing a small quantity of iron, sulphuret of iron, &c.

From these principles there is evidently required a quantity of sulphuret of iron and silex in an ore. Hence due attention must be paid to the proper admixture of siliceous and pyritous ores, and where either silex or iron pyrites are wanting they must be added. If limestone abound in an ore, the tendency to form infusible sulphuret of calcium, and the consequent sluggish flowing of slag is obviated by adding fluor spar, or where that is not at hand, by thoroughly washing the ores. The roasting process in heaps, as practised at Mannsfeld, on the Harz, &c., is more economical and superior to the English method of calcination in a flame-furnace. The smelting process in a blast-furnace resembling that, Pl. VII., figs. 1 and 2, is far superior to the English method in a flame-furnace.

COPPER AND METALLOIDS.

1. *Metal*. Copper, except titanium, is the only metal with a red color, and is capable of receiving a high lustre. Its crystals, native and artificial, belong exclusively to the regular system, 6-, 8-, 12-, 24-, and 4 × 6-hedra, with combinations 6-, 8-, and 12-hedra. It is somewhat sectile, very malleable, laminable, and ductile, (see *TENACITY*), elastic, sonorous, with a hackly fracture, and after hammering, somewhat silky. $H = 2\frac{1}{2} - 3$. Spec. grav. of the fused 8.91 — 8.921, of the unignited wire 8.939 — 8.949, of ignited wire 8.93, of flattened wire and sheet 8.95; by fusion in air oxygen is absorbed, pores produced, and its spec. grav. reduced to 8.7 — 8.8. It fuses at 1996°, is less fusible than silver, more than gold. Its powder, pressed and heated, is welded like platinum, if oxidation be prevented. Sym. Cu. Eq. 31.71 or 395.7.

Oxidation. By fusion, copper absorbs oxygen, passing through yellow and violet, and becomes covered by a black crust, externally oxide, internally suboxide; by a strong muffle-heat it may be almost wholly converted into

suboxide; heated to a strong white heat it burns with a light green color. Unchangeable in dry air at common temperatures, but in moist air, with carbonic acid, becomes dark olive-green (bronze) from carbonate, hydrate of oxide, and suboxide. It oxidizes under strong alkaline and in saline solutions. It decomposes steam slightly at a white heat. It decomposes heated oil of vitriol and nitric acids, evolving sulphurous acid and nitric oxide respectively. With any solution of acid in contact with air it gradually forms salts, and hence the danger of acid food standing in copper vessels.

Analysis. Its presence is known in solution by excess of ammonia producing a blue solution, by a precipitate of metallic copper by iron or zinc. Before the blowpipe, it gives a green color in the exterior flame to borax and mic. salt; in the inner-flame, it is reduced to suboxide, giving a ruby-red glass or enamel, especially upon the addition of tin, where the amount of copper is too small to give a greenish glass; if the heat be continued it is reduced to a globule of metal, especially in the salt of phosphorus; it is easily reduced by soda on charcoal, distinguished by its red color, and where iron occurs, the iron and copper are in separate globules. It is separated from alkalies, earths, iron, manganese, zinc, nickel, cobalt, chrome, uranium, &c., by sulphohydric acid gas; from lead by evaporating sulphates to dryness and dissolving in water, from gold, arsenic, antimony, &c., by sulphhydrate of ammonium. It is precipitated from its sulphate solution, where organic substances are not present, by boiling and adding caustic potassa, when it is obtained and weighed as black oxide of copper, from which the metal is calculated. See ANALYSIS and Tables.

2. *Oxygen.* a. *Red or Suboxide of Copper.* It occurs native. See RED COPPER ORE. *Prep.* 1. Calcine the metal by a strong muffle-heat. 2. Heat 5 pts. black oxide with 4 pts. copper filings, or 24 pts. anhydrous blue vitriol, and 29 pts. copper filings in a close crucible. 3. 100 pts. blue vitriol and 57 pts. cryst. carbonate of soda are mixed and dehydrated, powdered, mixed with 25 pts. copper filings, stamped into a crucible, kept 20 minutes at a white heat, and washed when cold with water. 4. Heat gently 5 pts. fused subchloride of copper with 3 pts. dry carbonate of soda in a close crucible, and wash out. 5. A blue solution of oxide of copper in sugar and soda, or potassa, precipitates red oxide by heating.

Prop. Cryst. Syst. Regular; spec. grav. 5.3—5.7; brownish red, in fine powder, and pure carmine-red; reducible to metal by gentle ignition with carbon or hydrogen. Comp. $\text{Cu}_2\text{O} = 71.42$ or 891.4, containing 88.78 pr. ct. copper. By heating fresh hydrated oxide with a solution of milk-sugar and a little carbonate of soda, a yellow hydrated suboxide is obtained. Suboxide decomposes with most acids into metal and a salt of oxide; a few, as muriatic, dissolve it unchanged, forming red or colorless solutions, from which the fixed alkalies, caustic and carbonated, separate an orange, yellow, and red; prussiate and hydri-

date of potassa, a white, brownish-red, and brownish-white precipitate respectively; its compounds oxidize readily and spontaneously in the air.

Use. It imparts a deep, rich, ruby-red color to glass, and from its oxidizing tendency, some care is requisite in the manufacture; the melted glass should not be exposed much to the air, and a little metallic tin assists and maintains the reduction. Its coloring power is so intense that it is usual to blow out colorless glass coated by a film of the red glass. Pastes colored by it imitate the ruby and garnet.

b. *Black Oxide of Copper.* The native oxide is termed COPPER BLACK. *Prep.* By igniting the carbonate, hydrate, or nitrate gently, the sulphate strongly, or the metal strongly, for some time in the air; by precipitating a boiling solution with caustic potassa; by heating the oxide with 4 to 6 times as much caustic potassa, and washing over, it remains in crystals.

Prop. A brownish black powder, fusing at a very high temperature, easily reduced at a low red heat by carbon and hydrogen to metal, by deoxidizing agents, protoxide of iron, protochloride of tin, fermentation, or boiling with many organic matters, to suboxide. Comp. $\text{CuO} = 39.71$ or 495.7, containing 79.83 pr. ct. copper. Its hydrate, obtained by precipitating a cold solution by dilute caustic alkali or lime, is greenish blue, changing easily into black oxide. VERDITER is a mixed hydrate and carbonate. It is this oxide which forms the usual salts of copper, acids readily uniting with it.

Salts. Anhydrous salts are generally white, the hydrous blue or green, generally soluble in water, reddening litmus. They are reduced by the metals, zinc, cadmium, tin, lead, iron, cobalt, nickel, bismuth, and by many organic substances, to metal or suboxide; precipitated by sulphuretted hydrogen and alkaline sulph hydrates, as brownish black sulphuret, insoluble in excess of precipitant, by fixed alkalies, caustic and carbonated, as bluish or greenish hydrate and carbonate, by ammonia, an excess of which redissolves the salt with violet-blue color; by iodide of potassium, white; chromate of potassa, reddish brown; phosphate of soda and oxalic acid, greenish white; yellow prussiate of potassa, dark-brown, dilute if reddish; red prussiate, brownish yellow. Guaiacum tincture is colored first blue and then green, when dilute by adding a little prussic acid. Some of these tests are extremely sensitive: 1 copper to 150,000 water is barely precipitated by iron if a drop of nitric acid be added; 1 Cu to 100,000 water is browned by sulphuretted hydrogen; 1 Cu to 2 or 500,000 water is reddened by yellow prussiate of potassa; 1 copper-salt to 450,000 colors guaiacum tincture.

c. *Cupric Acid.* Add nitrate of copper and a solution of bleaching salt with excess of lime, previously cooled below 32° ; the bluish green precipitate becomes purplish red, and is washed with cold lime-water. It appears to be Cu_2O_3 .

3. *Sulphur.* a. *Subsulphuret.* Found native as COPPER-GLANCE. *Prep.* By rubbing to-

gether 4 pts. fine copper filings and 1 pt. flowers of sulphur; by heating the same; by introducing copper-foil into vapor of sulphur; by igniting oxide of copper with sulphur; anhydrous blue vitriol in a charcoal crucible at a white heat yields 47.6 pr. ct. of the sulphuret with a few granules of the metal.

Prop. Grayish black, rather soft and sectile, with shining lustre, much more fusible than metallic copper, oxidizes by ignition in air to sulphurous acid, sulphate, and oxide of copper; soluble with difficulty in strong boiling muriatic acid, easily and perfectly in hot nitric, partially in cold nitric acid; decomposed partially by fusion with caustic and carbonated alkali, entirely with saltpetre; by ignition with oxide of copper into sulphurous acid and metal or suboxide ($\text{Cu}_2\text{S} + 2\text{CuO} = 4\text{Cu} + \text{SO}_2$, or $\text{Cu}_2\text{S} + 6\text{CuO} = 4\text{Cu}_2\text{O} + \text{SO}_2$). Comp. Cu_2S , containing 79.73 pr. ct. copper.

b. Sulphuret of Copper. See COPPER INDIGO. Formed by precipitating a solution of copper by sulphuretted hydrogen; it is brownish black, changing by exposure in a moist state to the air, by careful roasting, or in hot nitric acid, into more or less sulphate of copper. Comp. CuS , containing 66.3 pr. ct. metal.

c. Pentasulphuret of C. Bi-, tri-, tetra-, and pentasulphuret of potassium give black precipitates, which may be regarded as corresponding compounds of copper, or as mixtures of sulphuret and pentasulphuret. The 5-sulphuret is unchangeable in air, soluble in carbonated alkali.

Pelouze finds that the sulphuret produced by pouring a soluble sulphuret into a solution of a copper salt is an oxysulphuret, composed of $5\text{CuS} + \text{CuO}$.

d. Sulphocarbonate of C. Formed by adding sulphocarbonate of calcium to a salt of copper is black, soluble in excess of the precipitant.

4. Phosphorus. a. Phosphuret of C. By igniting copper with phosphorus, or with phosphoric acid and charcoal, phosphate of copper with charcoal, a mixed phosphuret of copper may be obtained, more fusible than copper, nearly as hard as steel, brittle, of a color passing from copper-red to steel-gray, in proportion to the per centage of phosphorus. A definite compound, Cu_3P , is obtained by passing hydrogen over phosphate of copper at a strong heat; a $\frac{2}{3}$ phosphuret, Cu_3P , by passing phosphuretted hydrogen over heated chloride of copper, and a $\frac{1}{3}$ phosphuret, Cu_6P , by passing the same over heated subchloride.

b. Subsulphophosphite of C. Bisulphuret of copper, obtained by precipitating a solution of blue vitriol in ammonia by soda liver of sulphur, is dried in vacuo, treated in a bulb cautiously with sulphuret of phosphorus, and gently warmed in a current of hydrogen. A yellow powder = $2\text{Cu}_2\text{S}, \text{PS}_3$. By heating to ignition in a retort, 2 eq. sulphur pass off, leaving brown subsulphophosphite, $2\text{Cu}_2\text{S}, \text{PS}$.

c. Hyposulphophosphite of C. Sulphuret of copper is dried in vacuo, and treated as under *b*; brown; CuS, PS . By gentle ignition in a retort there remains $\text{Cu}_2\text{S}, \text{PS}$. By warming 2 eq. of it with 4 eq. sulphur, there is formed a sulphophosphate, $2\text{CuS}, \text{PS}_3$, and by gently heating the last, $8\text{CuS}, \text{PS}_3$.

5. Nitruet of C. If dry ammoniacal gas be passed over black oxide of copper heated in a glass tube by an oil bath to 482° , heat is evolved, nitrogen and water produced, and the oxide transformed into a greenish powder, Cu_6N , which decomposes in the air at a heat of 572° into nitrogen and metallic copper.

6. Hydruet of C. Dissolve 10 pts. hypophosphite of baryta in water, and the baryta being exactly thrown down by sulphuric acid, add 8 pts. blue vitriol in strongest solution, heat the mixture not above 158° , to form a precipitate, first yellow, then orange; if bubbles of hydrogen escape, cool the vessel; the filtered deposit is washed in an atmosphere of carbonic acid by water free from air and dried between paper. The probable formula is Cu_2H . Wurz, *Comptes Rendus*, 1844.

Alloys. Copper combines readily with many metals, forming useful alloys. With zinc it forms BRASS; with zinc and nickel, ARGENTAN or German silver; with tin, BRONZE, cannon, bell-metal, and SPECULUM METAL; with GOLD and SILVER for coinage and plate. It forms reddish white, somewhat malleable alloys with manganese, molybdenum, tungsten and iron; brittle with arsenic, antimony, and bismuth. A small quantity of arsenic whitens copper, like silver, but renders it brittle. Copper fuses with silicium to a malleable bead; and copper heated powerfully with silica and charcoal, forms a compound containing carbon and silicium. Farther alloys see under IRIDIUM, PALLADIUM, PLATINUM.

HALOID SALTS.

1. Chlorine. a. Subchloride of Copper. Sym. Cu_2Cl . Chloride of mercury heated with copper yields metallic mercury and subchloride of copper. It is also formed by igniting chloride of copper apart from the air, or by reducing it by sugar, &c. (see *Suboxide*). A copper plate immersed in muriatic acid becomes covered with white tetrahedra of this salt. It is white, becoming bluish by light, fusible, gradually changing in the air to basic chloride if dry, rapidly if moist, is insoluble in water and dilute sulphuric acid, soluble in muriatic acid, in a solution of ammonia or common salt. A basic subchloride is formed by heating the basic chloride.

b. Chloride of C. Prep. 1. By dissolving oxide or carbonate of copper in muriatic acid; the metal in nitro-muriatic acid; exposing the metal in muriatic acid to the air; from the subchloride by gradual oxidation in the air, or by its rapid oxidation with nitric acid. 2. Mix equal pts. of blue vitriol and common salt with a little water at 122° to 140° , and when sulphate of soda separates on cooling, and by slow evaporation, or at 68° , the rest of this salt and the excess of common salt separate, the chloride separates in crystals from the decanted liquid. *Rieckher, Ch. Gaz.* iii. 394.

Prop. $\text{CuCl} = 67.18$ or 838.35 , with 47.2 pr. ct. copper. The solution evaporated yields 4-sided prisms, $\text{CuCl}, 2\text{HO}$, green, deliquescent, soluble in water, alcohol, and ether, losing most water at 212° , losing water by cold oil of vitriol, and becoming brown, dry chloride, which is fusible and sublimable.

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c. *Basic Chloride of C.* See ATACAMITE. Formed by digesting hydrated oxide of copper in a solution of chloride, or exposing copper moistened with salammoniac to the air, and washing the powder (*Brunswick green*). A green powder, soluble in acids, not in water; Comp. $\text{CuCl}, 3\text{CuO} + 4\text{HO}$. Loses water by heat and becomes brownish black. By precipitating chloride of copper with an insufficient quantity of potassa, a pale green powder falls, $\text{CuCl}, 2\text{CuO} + 4\text{HO}$, which becomes black by heating strongly, $\text{CuCl}, 2\text{CuO}$, but kept at 208° is brown, $\text{CuCl}, 2\text{CuO} + \text{HO}$; the black compound moistened becomes $\text{CuCl}, 2\text{CuO} + 3\text{HO}$.

d. *Chloride of C. and Ammonia.* The ammonium-chloride is formed by mingling saturated solutions of salammoniac and chloride of copper. Blue rhombs, soluble in water. Form. $\text{CuCl}, \text{NH}_4\text{Cl} + 2\text{HO}$.

According to Heumann this salt forms rhomboidal tablets and has the formula $\text{CuCl} + \text{NH}_4\text{Cl} + 4\text{HO}$. When concentrated chloride of copper is redissolved in ammonia, the blue octahedra separating from the solution are $\text{CuCl} + 6\text{CuO} + 6\text{HO}$. *Heumann*.

By saturating warm chloride of copper with ammonia-gas, ammonia-chloride of copper is formed, CuCl, NH_3 , decomposable by water, which dissolves a biammonia-chloride, $\text{CuCl}, 2\text{NH}_3$. The last is blue, crystallizable. When dry chloride is saturated with ammonia gas, a blue triammonia-chloride is formed, $\text{CuCl}, 3\text{NH}_3$.

e. By cooling strong solutions of chloride or subchloride of copper and potassium, double salts are obtained, the former quadratic octahedra, $\text{KCl}, \text{CuCl} + 2\text{HO}$, the latter regular 8-hedra, anhydrous, $2\text{KCl}, \text{Cu}_2\text{Cl}$.

2. *Bromide of C.* Formed by dissolving oxide of copper in bromohydric acid, or the metal in nitrobromohydric acid, and evaporating. The solution browns and yields green crystals, $\text{CuBr}, + 5\text{HO}$, which by heat separate into bromine and subbromide of copper, Cu_2Br . There is also a basic salt similar to the chloride. The dry bromide absorbs ammonia, forming $2\text{CuBr}, 5\text{NH}_3$. Alcohol precipitates another, $2\text{CuBr}, 3\text{NH}_3$, from a saturated solution of bromide in ammonia.

3. *Subiodide of C.* Precipitate a copper-salt by iodide of potassium, in which $\frac{1}{2}$ the iodine is set free and must be washed off with alcohol; or dissolve blue vitriol in aqueous sulphurous acid, and precip. by iodide of potassium. A brownish white powder, fusible, decomposed by nitric and sulphuric acids, by alkali. It absorbs ammonia, forming a white powder, $\text{Cu}_2\text{I}, 2\text{NH}_3$. By adding a saturated solution of iodide of potassium in excess, to a saturated solution of blue vitriol or verdigris in ammonia, a blue powder falls which may be crystallized. $\text{CuI}, 2\text{NH}_3 + \text{HO}$.

4. *Fluorine.* a. *Sulphuride of C.* Hydrated suboxide in contact with fluohydric acid immediately becomes red, fusible, insoluble subfluoride, Cu_2F . A silico-subfluoride, $3\text{Cu}_2\text{F}, 2\text{SiF}_3$, resembles it in color and other properties.

b. *Fluoride of C.* Dissolve oxide or carbonate of copper in an excess of fluoric acid, and

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evaporate the blue solution as it crystallizes. $\text{CuF}_3 + 2\text{HO}$. It forms green, soluble, double salts, with the alkalies and alumina. If carbonate of copper be in excess, or the blue fluoride be treated with hot water, a pale green, insoluble, basic fluoride is formed, $\text{CuF}, \text{CuO} + \text{HO}$.

c. A *borofluoride* is formed by double decomposition with borofluoride of barium and sulphate of copper; blue, crystalline needles, deliquescent, CuF, BF_3 . The *silicofluoride* forms blue prisms, with 21 eq. water, 2 eq. of which are lost by efflorescence.

OXYSALTS.

Salts of Red or Suboxide.

1. *Sulphite of Suboxide of C.* By the action of sulphurous acid on hydrate or carbonate of copper, sulphate of oxide dissolves and sulphite of suboxide remains, or by an alkaline sulphite a similar result is obtained; if a caustic potassa solution be saturated with sulphurous acid, and added to a solution of blue vitriol, the filtered solution by warming yields it in crystals. Brilliant red, unchangeable when dry, yielding water and sulphurous acid by distillation in a retort, easily decomposed by boiling; and, by sulphuric acid; insoluble in water, soluble in muriatic and sulphurous acids, and ammonia. There is a double insoluble salt of sulphite of copper and potassa.

2. The hyposulphite, formed from blue vitriol and hyposulphite of lime is a colorless solution. The double salt, with potassa, is a yellow powder, difficultly soluble, easily decomposed; form. $\text{KO}, \text{S}_2\text{O}_2 + \text{Cu}_2\text{O}, \text{S}_2\text{O}_2 + 2\text{HO}$. Another compound is formed by precipitating the solution of the above by alcohol; form. $3(\text{KO}, \text{S}_2\text{O}_2) + \text{Cu}_2\text{O}, \text{S}_2\text{O}_2 + 3\text{HO}$. A yellow salt of soda has the form. $2(\text{NaO}, \text{S}_2\text{O}_2) + 3(\text{Cu}_2\text{O}, \text{S}_2\text{O}_2) + 5\text{HO}$, and another white salt, $3(\text{NaO}, \text{S}_2\text{O}_2) + \text{Cu}_2\text{O}, \text{S}_2\text{O}_2 + 2\text{HO}$.

3. Red copper-glass contains a silicate of red oxide, the cause of the red color, and another silicate appears to exist in some tile-ores, and in some of the copper ores from Lake Superior.

Salts of Black Oxide.

Sulphur. 1. *Sulphate of Copper.* Syn. Blue vitriol. *Ger.* Kupfervitriol. *Fr.* Vitriol bleu, V. de Cuivre. Found native, but made largely for use in the arts, chiefly from sulphuret of copper by roasting, more rarely from the metal and sulphuric acid.

Prep. 1. By a careful calcination of copper-stone (see above the processes for metallurgical treatment of copper ores) in a reverberatory, a sulphate of copper is formed, which is extracted by lixiviation, and more may be obtained by adding oil of vitriol previous to lixiviation. If the heat be pushed far enough, much iron will be rendered insoluble. 2. Copper, 3 pts., is ignited in a close reverberatory, and 1 pt. sulphur being then thrown on, the two unite by combustion to sulphuret of copper, which by calcination is converted into sulphate of oxide and suboxide. It is thrown into vats for solution, sulphuric acid being often added, and the insoluble residue again

treated in the furnace by sulphur and air. 3. Sulphuretted copper ore is rarely pure enough to be subjected immediately to roasting, nor oxidized copper ore for direct treatment with sulphuric acid.

The solutions of blue vitriol when duly concentrated crystallize without difficulty. As a mixture of copper and iron vitriol is often employed in the arts, it is not always necessary to obtain blue vitriol free from iron; but if it be desired thus to free it, the sulphates heated to beginning redness in an iron vessel or a reverberatory, will leave nearly all the iron salt insoluble, together with a little of the copper, the rest of which may be extracted with boiling water, or more slowly by cold water. The insoluble residue treated with sulphuric acid, yields the residue of the copper and much iron, which may be added to a fresh portion of mixed vitriol, or the copper thrown down by cementation with iron.

Prop. Azure-blue, (greenish blue, if impure from iron,) transparent crystals of the doubly oblique rhombic or triclinic system, presenting elongated rhombs; spec. grav. 2.274; composition:

	eq.	H=1	O=100	in 100 pts.
CuO	1	40.00	495.70	32
SO ₃	1	40.00	501.16	32
HO	5	45.00	562.40	36
		125.00	1559.26	100

Form. CuO, SO₃ + 5 HO. The anhydrous

Dry sulphate.....	CuO, SO ₃
Cryst. sulphate	CuO, SO ₃ + 5 HO
Trisulphate.....	CuO, SO ₃ + 2(CuO, HO)
1st tetrasulphate	CuO, SO ₃ + 3(CuO, HO)
2d tetrasulphate.....	CuO, SO ₃ + 3(CuO, HO) + HO
3d tetrasulphate.....	CuO, SO ₃ + 3(CuO, HO) + 2 HO
1st pentasulphate	CuO, SO ₃ + 4(CuO, HO)
2d pentasulphate.....	CuO, SO ₃ + 4(CuO, HO) + 2 HO

3. *Sulphate of C. and Ammonia* is formed by crystallizing a mixed solution of the two salts. Light-blue, very soluble in water, composed of NH₄O, SO₃ + CuO, SO₃ + 6 HO. By supersaturating concentrated blue vitriol solution with ammonia to perfect solution, and by gentle evaporation, or by strong cooling, or by adding alcohol, there are formed deep-blue prisms (in the last case a powder) of ammonia sulphate of copper, composed of 2 NH₃ + CuO, SO₃ + HO, soluble in 1½ pts. water, and decomposing in the air. If this salt be heated to 300°, it becomes apple-green, forming NH₃ + CuO, SO₃, which readily assumes 3 eq. water, and by heating to 400° it becomes NH₃ + 2(CuO, SO₃). Dry sulphate of copper absorbs 53.97 pr. ct. dry ammoniacal gas, evolving heat and swelling up to a blue powder, soluble in water with a deep azure-blue color; form. 5 NH₃ + 2(CuO, SO₃).

4. *Sulphate of C. and Potassa.* Formed by crystallizing a mixture of the two salts; is light-blue, very soluble, composed of KO, SO₃ + CuO, SO₃ + 6 HO, loses 2 eq. water at 212°, and deposits a green basic double salt by boiling, and at a higher heat fuses with loss of some acid. The double salt with soda is

salt contains 32 pr. ct. oxide of copper. 1 pt. of the cryst. salt is soluble in 3.32 at 39.2°; 2.71 at 66.2°; 1.84 at 87.8°; 1.7 at 100°; 1.14 at 122°; 1.07 at 167°; 0.75 at 190°; 0.55 at 212°. (*Brandes and Firnhaber.*) Soluble in 2.412 at 64°, with a spec. grav. of 1.182. (*Karsten.*) It is therefore soluble in 3 pts. cold and ½ pt. boiling water. By heating it at 100° in vacuo it loses 4 eq. water, becoming white, and requires from 430° to 467° to expel the last eq. water. The anhydrous salt is obtained in colorless crystals by the action of cold oil of vitriol on copper in close vessels. Blue vitriol, rendered anhydrous by heat, is white and opaque, attracts water again from the air, requires strong ignition to expel its acid, which passes off partially decomposed, and if charcoal be present, mixed sulphuret and metallic copper remain at a high heat, while a lower heat leaves the metal alone.

2. *A basic sulphate*, the mineral *BROCHANTITE*, is formed by partially precipitating blue vitriol with caustic alkali, by digesting fresh carbonate or hydrate of copper in blue vitriol solution, by exposing ammonia-sulphate solution to the air. It is pale-green, insoluble, easily decomposed by heat into water, sulphate and oxide of copper. It is probably a mixture of two basic salts, and is between 4 CuO, SO₃ + 4 HO and 3 CuO, SO₃ + 3 HO. According to Kane, another basic salt, 8 CuO, SO₃ + 12 HO is formed by exactly precipitating blue vitriol with caustic potassa.

J. D. Smith, in *Trans. Chem. Soc.* 1843, on the subsulphates gives the following table:

obtained by mixing blue vitriol and bisulphate of soda, Glauber's salt and blue vitriol first crystallizing, then the double salt. Oxide of copper and magnesia being isomorphic, a double salt of sulphate of copper, magnesia, and ammonia may be formed direct.

5. *Hyposulphate of C.* Obtained by exact double decomposition of blue vitriol and hypsulphate of baryta, forms rhombic prisms, very soluble in water, not in alcohol. Form. CuO, S₂O₅ + 4 HO. By adding insufficient ammonia, a basic salt precipitates, composed of 4 CuO, S₂O₅ + 4 HO.

6. *Ammonia-hypsulphate of C.* Formed by supersaturating dilute hypsulphate of copper with ammonia, crystallizes in azure square tables, difficultly soluble, permanent in air; composed of 2 NH₃ + CuO, S₂O₅.

Use. Blue vitriol meets with extensive employment in the arts, as in the preparation of *VERDITER*, and various blue and green pigments, in galvanoplastics, as a reserve in the cold indigo-vat, and together with green vitriol for black dyes on woollen yarn and cloth, furs, &c. Runge recommends the ammoniacal solution for permanent light-blue. *Farben-chemie.*

COPPER.

Phosphorus. 1. *Phosphate of C.* $2\text{CuO}, \text{PO}_5$. Formed by double decomposition with blue vitriol and phosphate of soda; is a greenish powder, insoluble in water, soluble in muriatic, phosphoric, acetic, and other acids, scarcely in ammoniacal salts; becomes brown by heating.

2. *Basic Phosphates.* A variety of these have been found native, for a tabular view of which, see ARSENIOPHOSPHATES.

3. *Phosphite of C.* Formed by chloride of copper and phosphite of ammonia; is a blue precipitate, decomposed by heat into metal and phosphate of copper.

4. *Hypophosphite of C.* is only known in the solution of hydrate of copper in cold hypophosphorous acid, and is reduced by concentration.

1. *Nitrate of C.* Easily obtained by solution of copper, its oxides, hydrate or carbonate in nitric acid. Thus where the metal is used, $\text{Cu}_3 + 4\text{NO}_5 = 3(\text{CuO}, \text{NO}_5) + \text{NO}_2$, the last absorbing oxygen as it rises in the air, and forming the red fumes NO_4 . The neutral salt requires at least 3 eq. water, and hence if too strong acid be employed, green, basic salt remains, insoluble in water. The greenish solution becomes blue and deposits at very low temperatures crystals containing 6 eq. water, at higher temperatures prisms with 3 eq. water. Form. $\text{CuO}, \text{NO}_5 + 3\text{HO}$, with 33 pr. ct. oxide of copper. The crystals deflagrate on ignited coals, with phosphorus under the hammer; when powdered and rolled up in tin-foil spontaneous ignition results after a short time. Paper dipped into its solution and dried, takes fire readily below a red heat, and burns with a green flame. The basic salt, $3\text{CuO}, \text{NO}_5 + \text{HO}$ (Graham), is also formed by gently heating the neutral salt in solution with a little alkali, oxide, hydrate, or carbonate of copper; it is a green powder, soluble in acids, not in water, easily reduced by ignition to black oxide. Gerhardt's analyses of the subnitrate gave $4\text{CuO}, \text{NO}_5 + 3\text{HO}$, or $\text{CuO}, \text{NO}_5 + 3(\text{CuO}, \text{HO})$, which is the more probable composition.

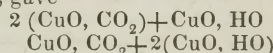
2. *Ammonia Nitrate of C.* Obtained in deep blue crystals by supersaturating a strong solution of the nitrate with ammonia, or by passing ammoniacal gas into the hot saturated solution of the nitrate until resolution takes place; easily decomposed by heat with deflagration; form. $2\text{NH}_3 + \text{CuO}, \text{NO}_5$.

Halogens. 1. *Chlorate of copper* obtained by direct process, forms greenish deliquescent crystals. The *perchlorate* similarly formed, yields blue deliquescent crystals. Both deflagrate on ignited coals. *Iodate of copper* may be obtained by double decomposition, but better by direct action; soluble in 302 pts. water at 59° , in 154 pts. at 212° , in ammonia with a dark blue color, decomposed by heat, leaving oxide of copper. The *periodate* is green. A solution of carbonate of copper in bromic acid yields bluish green crystals of *bromate*, composed of $\text{CuO}, \text{BrO}_5 + 5\text{HO}$. Both bromate and iodate form blue ammonia salts, the former with the form. $2\text{NH}_3 + \text{CuO}, \text{BrO}_5$.

Carbonate of C. For the native compounds see MALACHITE, BLUE MALACHITE. Copper

COPPER-FROTH.

has a feeble affinity for carbonic acid, for when a salt of copper is precipitated by carbonate of soda, carbonic acid escapes, and the voluminous bluish green precipitate is a mixed hydrate and carbonate, from which long washing or warming in water seems to remove the greater part of or all the carbonic acid. Some few green pigments of this nature are employed in the arts, as Mineral Green, VENDERITER. They are, however, objectionable from their liability to change alone or in contact with other substances. Favre's examination of the carbonates obtained from the solution of carbonate of copper in sesquicarbonate of ammonia, gave



Borate of C. Formed by double decomposition is a pale green powder, slightly soluble in water, fusing to a green, opaque glass.

Silicate of C. Oxide of copper imparts a green tint to glass. A solution of waterglass gives a greenish blue precipitate with salts of copper. Native compounds are CHRYSOCOLLA, DIOPHASE.

COPPER. *Min.* Syn. Native Copper; Octahedral Copper. Cryst. system, Regular, comb. 6-, 8-, 12-, 24-, 4×6 -hedron; also aborescent, filiform, amorphous. H. = 2.5–3, G. = 8.584. It has the usual characters of metallic copper. It has numerous localities, being rarely absent from a copper-mine. Some of the most remarkable specimens are a mass in the museum at Lisbon, from a valley near Bahia, weighing 2616 lb.; the mass, lately removed to Washington, from the Ontanawgaw river, near Lake Superior, and supposed by Schoolcraft to weigh 2200 lb.; many other large masses have been observed near the same lake; near New Brunswick, New Jersey, a vein or sheet of copper $\frac{1}{16}$ to $\frac{1}{8}$ inch thick was traced for several rods.

COPPERAS. *Min.* Syn. Hemiprismatic Vitriol-Salt; Green Vitriol. Cryst. system Oblique Rhombic; rarely well crystallized. Resembles green vitriol in external and chemical characters (see Protosulphate of Iron); taste, sweetish, astringent, metallic. Form. $\text{FeO}, \text{SO}_3 + 7\text{HO}$. It arises from the decomposition of Iron Pyrites, and is most frequently found in old mines.

COPPER BISMUTH. *Min.* Pale lead gray, passing into tin-white, with black streak. Neither the sulphur nor the bismuth were determined correctly in Klaproth's analysis, but the formula may be $2\text{Cu}_2\text{S} + \text{Bi}_2\text{S}_3$. Found at Wittichen in Fürstenberg.

COPPER-FROTH. *Min.* Syn. Prismatic Euchloro-Malachite; Pharmacosiderite; Kupaphrite; Cupriferous Calamine. *Descrip.* Cryst. system, Right Rhombic. H. = 1–1.5 G. = 3.098. Pale apple-green, and verdigris-green with bluish tint; lustre of P, pearly, of other faces vitreous; translucent; sectile; thin lamina flexible.

Chem. relations. Decrepitates before the blow-pipe, fusing to an amorphous pearl; gives off arsenical fumes, and reduces to a white reguline mass. Formula, $5\text{CuO}, \text{AsO}_5 + 10\text{HO}$ (or 9 HO). If the carbonate of lime is essential, one eq. CaO, CO_2 must be added.

COPPER-GLANCE.

Local. It occurs with other ores of copper generally in divergent fibrous groups. In the Bannat; Liebethen, Hungary; Nerzschinsk, Siberia; Schwartz, in Tyrol; Saalfeld, Thuringen; Matlock, Derbyshire.

COPPER-GLANCE. *Min.* Syn. Vitreous Copper; Prismatic Copper-glance. *Descrip.* Cryst. system, Right Rhombic; frequently compounded like Arragonite; also granular. $H. = 2.5 - 3$. $G. = 5.5 - 5.8$. Color and streak, blackish lead-gray; often tarnished blue and green; lustre metallic; sectile; fracture conchoidal.

Chem. relations. Colors flame bluish, fuses on charcoal in the outer flame, evolving sulphurous acid; congeals in the inner flame; gives the reactions of copper, and with soda a globule of the metal; soluble in nitric acid. Form. Cu_2S , containing $Cu\ 80 + S\ 20 = 100$.

Local. Some of the finest specimens are from Cornwall; it also occurs at other places in Europe, massive and crystallized. In the U. S., at Sunbury, Bristol, Cheshire, Conn.; Schuyler's mines, New York; in Blue Ridge, Orange Co., Virginia; near New Market, east of the Monocacey, Maryland, &c.

COPPER GREEN. *Min.* See **CHRYSO-COLLA**.

COPPER INDIGO. *Min.* Massive, spheroidal; $G. = 3.8$; deep indigo-blue; lustre feeble, resinous; opaque; streak lead-gray, shining; sectile. Behaves like the preceding, but remains fluid in the inner flame. Form. CuS , containing $Cu\ 66.3 + S\ 33.7 = 100$. It occurs at a copper mine near Badenweiler, and at Vesuvius.

COPPER-MICA. *Min.* Syn. Rhombohedral Euchlore-malachite. Cryst. system, Hexagonal; hemiedric; an acute rhomb, with terminal planes, c ; cleaves perfectly, parallel to c . $H. = 2$. $G. = 2.549$. Grass-green, with paler streak; lustre vitreous, of c pearly; sectile. It behaves before the blowpipe like copper-froth; perfectly soluble in acids and ammonia. Form. $8CuO, AsO_5 + 12HO$; containing $CuO\ 58.7 + AsO_5\ 21.3 + HO\ 20 = 100$. It occurs in copper mines in Cornwall.

COPPER NICKEL. *Min.* Syn. Prismatic Nickel-Pyrites. *Ger.* Kupfernickel; Nickelnickies; Rothnickelkies. Cryst. Hexagonal; massive, granular, columnar, $H. = 5 - 5.5$. $G. = 7.33 - 7.655$. Orange-red; metallic; opaque; streak brownish; brittle; fracture uneven. In a closed tube it sublimes no arsenic, but a little arsenious acid; on charcoal fuses to a white, brittle, metallic globule, giving off arsenical fumes; after calcination fluxes show the presence of nickel, and sometimes of cobalt; soluble in nitric and nitromuriatic acids, with a green color. Form. Ni_2As , containing $Ni\ 44 + As\ 56 = 100$. It usually contains also cobalt, iron, lead, and sulphur in small quantities, and Berthier has shown that a portion of arsenic is sometimes replaced by antimony. It occurs accompanying cobalt at Annaberg, Schneeberg, Saxony; Thuringen; Riechelsdorf, Hessen; Styria; Dauphiny; Cornwall. In the U. S., Chatham, Conn.; on the Schuylkill, 10 to 15 miles from Philadelphia, Penn. See **ARSENICAL NICKEL**.

COPPER PYRITES.

COPPER PYRITES. *Min.* Syn. Pyramidal Copper Pyrites. Octahedral Copper Pyrites. Pyritous Copper. Yellow Copper Ore. *Ger.* Kupferkies. *Fr.* Cuivre Pyriteux. *Descrip.* Cryst. system, Quadratic. It also occurs globular, botryoidal, stalactitic, and other shapes—texture impalpable; granular, often impalpable—particles strongly coherent. $H. = 3.5 - 4$. $G. = 4.159 - 4.169$. Color brass-yellow; subject to tarnish; opaque; fracture conchoidal, uneven; rather sectile; lustre metallic; streak greenish black, a little shining.

Behavior. Fuses on charcoal to a steel-gray globule, brittle, with reddish fracture, and after long blowing magnetic; with borax and soda it gives a globule of metallic copper; in a closed or open tube it gives no sublimate, in an open tube evolves sulphurous acid; with borax and mic. salt, it gives, after roasting, the reactions of iron and copper; soluble in muriatic acid, leaving the greater part of the sulphur.

Analysis. 1. By H. Rose; 2. by Phillips; 3. by Berthier; 4. by Thomson.

	1.	2.	3.	4.
S	35.87	34.46	36.3	34.655
Cu....	34.40	31.20	32.1	33.640
Fe	30.47	30.80	31.5	31.535
	0.27	1.10	—	0.555
	101.01	97.56	99.9	100.385

The last line consists of gangue. Form. $Cu_2S + Fe_2S_3$.

Local. Copper pyrites is the principal ore of copper at the Cornish mines. It is there associated with tin, galena, blende, and other ores of copper. The copper beds of Fahlun, in Sweden, are composed principally of this ore, which occurs in large masses, surrounded by a coating of serpentine, and imbedded in gneiss. At Rammelsberg, near Goslar in the Hartz, it forms a bed in graywacke slate, and is associated with iron pyrites, galena, blende, and minute portions of silver and gold. The Kurprinz mine at Freiberg affords well defined crystals. It occurs also in the Bannat, Hungary, Thuringia, &c.

In the U. S. it has been found in many places, but generally in small quantities. It occurs at the Southampton Lead Mines, Mass., at Turner's Falls on the Connecticut, near Deerfield, and at Hatfield and Sterling, Mass.: at Strafford and Shrewsbury in Vermont, with magnetic pyrites; in New Hampshire, at Franconia, in gneiss; at Unity, Warren, Eaton, Lyme, Haverhill, and elsewhere: in Maine, at the Lubec lead mines, and at Dexter: in New York, at the Ancram lead mine; five miles from Rossie; at the Rossie lead mine in crystals; and in crystals and massive at the mine near Wurtzborough, Sullivan Co.: in Virginia, at the Phenix copper mines, Fauquier Co., and the Walton gold mine, Luzerne Co.: in the Catoctin Mts., Maryland, and between Newmarket and Taneytown. *Dana*.

It has been latterly found near Princeton, N. J.; in the Coal Region, Penn., and on the Schuylkill not far from Philadelphia; in Madison and Wayne Cos., Missouri, in sufficient

COPPER URANITE.

quantities to be worked. For the reduction of this ore see *Metallurgic treatment of COPPER.*

COPPER URANITE. See URANITE.

COPPER-VELVET. *Min. Ger.* Kupfer-sammterz. It occurs in globules or druses, composed of delicate velvety fibres, of a rich blue color and pearly lustre, containing oxides of copper and zinc, with sulphuric and silicic acids. *Local.* Moldawa in the Bannat.

COQUIMBITE. *Min. Syn.* White Cop-peras, Neutral persulphate of iron. It occurs granular, and crystallized in hexagonal prisms; white or pale violet; soluble in water; evolves water in a closed tube; leaves peroxide of iron by ignition. Rose's analysis gives 43.5 sulphuric acid, + 26 peroxide of iron, + 30 water, leading to the formula $\text{Fe}_2\text{O}_3, 3\text{SO}_3 + 9\text{HO}$.

1. The foliated coating of coquimbite, called *yellow copperas*, behaves like it, and is composed, according to Rose, of sulphuric acid 39.6, + peroxide of iron 28, + water 29.6 corresponding with $2\text{Fe}_2\text{O}_3, 5\text{SO}_3 + 18\text{HO}$.

2. The radiated associate of coquimbite, according to Rose, contains sulphuric acid 31.7, + peroxide of iron 28, + water 36.5, with a formula $2(\text{Fe}_2\text{O}_3, 2\text{SO}_3) + 21\text{HO}$. The above 3 species also contain small quantities of lime, magnesia, and silica, with a little alumina included with the iron.

3. The *Vitriolochre* of Fahlun is, according to Berzelius, $2\text{Fe}_2\text{O}_3, \text{SO}_3 + 6\text{HO}$.

4. Prideaux's Fibroferrite appears to be $3\text{Fe}_2\text{O}_3, 5\text{SO}_3 + 27\text{HO}$.

5. Another yellow copperas from the brown coal of Kolosoruk, near Bilin, Bohemia, was found by Rammelsberg to consist of $4(\text{Fe}_2\text{O}_3, \text{SO}_3) + \text{KO}, \text{SO}_3 + 9\text{HO}$.

6. Scheerer's analysis of one from the alum-slate of Modum, Norway, led to the formula $4(\text{Fe}_2\text{O}_3, \text{SO}_3) + \text{NaO}, \text{SO}_3 + 9\text{HO}$, a remarkable agreement with the preceding, with soda instead of potassa.

The above 1 to 6 basic sulphates of iron cannot yet be properly classed as species, until their relation to others is better determined.

CORAL. *Tech.* Red and White. The red coral used in jewelry is the internal skeleton of the *Corallium rubrum*; a species of the Corollina genus of marine organized arborescent bodies. It consists chiefly of carbonate of lime and oxide of iron, the red coral being due to the latter ingredient.

CORDIERITE. *Min. Syn.* Prismatic quartz, *Mohs.* Dichroite, Iolite, Peliom, Steinheilite, Hard Fahlunite. *Descrip.* Cryst. Right Rhombic, consisting of vertical and horizontal prisms and terminal planes; also granular but coherent. $H. = 7$ to 7.5 . $G. = 2.6$ to 2.66 . Color blue, generally blackish, deep blue in the direction of the vertical axis, yellowish perpendicular to it, whence Dichroite; vitreous; transparent, translucent; fracture subconchoidal.

Behav. and Compos. All but the Hard Fahlunite fuse with difficulty on the edges, dissolve slowly and entirely in borax and mic. salt, leaving silica in the latter; do not dissolve with soda, forming with a little a vitreous slag; cobalt solution renders them black; not

CORK.

soluble in acids. The Hard Fahlunite differs in fusing alone or with some soda to a colorless, semitransparent glass, and giving a blue glass with cobalt solution. Formula of the

former $2 \left[\frac{3\text{MgO}}{3\text{FeO}} \right] 2\text{SiO}_3 + 5(\text{Al}_2\text{O}_3, \text{SiO}_3)$; of Hard Fahlunite $2(3\text{MgO}, 2\text{SiO}_3) + 3 \left[\frac{\text{Al}_2\text{O}_3}{\text{Fe}_2\text{O}_3} \right] \text{SiO}_3$.

Local. Bodenmais; Capo de Gata, Spain; Orriervi, Finland; Tunaberg, Sweden; Arendal, Norway; Ujordlevsoak, Greenland; Ceylon, &c. In U. S. Haddam, Conn; Brimfield, Mass.; Richmond, N. H. From its dichroism it is sometimes employed as a gem.

CORIANDER. The seeds of the *Coriandrum Sativum*, Trommsdorff's analysis gave

Volatile oil.....	0.47
Stearin	6.00
Olein	7.00
Colored extract and malate of potassa, mucilage, azotized extractive, salts of vegetable acid and tannin.....	7.50
Vegetable fibre.....	65.20
Water	9.73

Volatile oil is of spec. grav. 0.759. Alcohol and ether both dissolve it, and nitric acid transforms it into a green resinoid mass. Sulphuric acid dissolves it and changes its color to a brownish yellow. With iodine it explodes. (*Liebig.*) It belongs to the oxygen class of volatile oils.

CORK. *Tech.* Title corrupted from *Cortex* (Lat.). The bark of the *Quercus Suber*, a species of oak, native to the southern parts of Europe. The action of ether and alcohol upon finely comminuted particles develops yellow acicular crystals of *Cerin*, so called from its waxlike properties: the residual mother liquid, consisting chiefly of tannin and extractive matter. The reddish gray portion of the cork *Suberin*, left undissolved by the alcohol and ether, when treated with nine times its weight of nitric acid of spec. grav. 1.30 and heated, is transformed into new products. On the surface of the hot liquid a fluid waxy mass *Ceric acid*, collects and can be removed: the subjacent solution diluted with water, drops white flocculæ, which are separable by filtration. This precipitate is the *cork-cellulose*, $(\text{C}_{22}\text{H}_5\text{O}_{10})$, analogous to the lignin of Chevreul and Payen. From the filtered liquor crystals of suberic and oxalic acids are obtained, the two being easily separable by cold water, in which the former is but slightly soluble.

Cerin or cork wax $(\text{C}_{25}\text{H}_{10}\text{O}_3)$, is changed in color, but not dissolved by potassa of 1.27 spec. grav., though the addition of an acid to the ley precipitates a minute portion of brown matter. Nitric acid converts it into *ceric acid*, a brownish yellow, transparent, waxy mass, insoluble in hot and cold water, but soluble in alcohol, ammonia, and potassa, from the two latter of which it is separable by the acids. In chemical properties it is related to the fat acids, and consists of $\text{C}_{42}\text{H}_{17}\text{O}_{13}$.

The formation of this acid from *Cerin*, therefore, is easily explained by taking 4 eq.

CORNEOUS LEAD.

of that substance and comparing its relative number of equiv. with the formula of anhydrous ceric acid. Carbon and hydrogen remain after the deduction of the ceric acid.

Dropping.

4 eq. of cerin.....	= 100 C	40 H	12 O
1 eq. of ceric acid.....	= 42 C	16½ H	12 O
	58 C	23½ H	

But as the oxidation of cerin by nitric acid demonstrates the formation of carbonic acid, oxalic acid, and water, these together with ceric acid may be considered as the result of its decomposition by that reagent. *An. der Ch. und Ph.* 1843. See SUBERIC ACID.

CORNEOUS LEAD. *Min. Syn.* Orthotomous Lead-Baryte, *M.*; Bleihornierz. *Descrip. Cryst.* Quadratic, 1st and 2d vertical prisms and end-planes predominating, cleaving brightly parallel to prism. Color white, gray, and yellow; adamantine; transparent, translucent; rather sectile, with white streak. *Behav.* Fuses in the exterior flame to an opaque, yellow globule, white when cold, and with crystalline surface; in the inner flame is reduced; soluble in nitric acid with effervescence. Form. $PbCl + PbO, CO_2$. *Local.* Matlock, Derbyshire; Hausbaden, Badenweiller, Germany; in U. S. at Southampton, Mass.

CORNUS FLORIDA. *Phar. Chem. Syn.* Dogwood. The bark, analyzed by Walker and Cockburn, yielded gum-resin, tannin, gallic acid, fatty matter, oil, a crystalline substance, bitter extractive, wax, coloring matter, lignin, and earthy salts. There are two subspecies of the cornus, the *C. Circinata*, and *C. Sericea*.

Carpenter mistook the above-mentioned crystalline matter for a new alkaloid, and some years since announced it under the name of *Cornin*, but the subsequent researches of Blaney refuted this idea, and his position still more latterly has been confirmed by Geiger, who declares *cornin* to be a crystallizable resin, and that besides it there is also present in the plant a bitter principle, soluble in water and alcohol, and endowed with acid properties.

CORROSIVE SUBLIMATE. See MERCURY.

CORTICIN. An inodorous, tasteless substance, existing in the bark of the Aspen tree. (*Braconnot.*) It softens in boiling water; is soluble in alcohol and acetic acid, and precipitable from the last by water and sulphuric acid. The resinous extract of the *Salix alba* is said to be identical with Braconnot's corticin.

CORUNDUM. *Min. Syn.* Oriental Amethyst, Topaz, Ruby; Sapphire; Emery, *Ger.* Schmergel; Adamantine Spar, *Ger.* Demant-spath. *Descrip. Cryst.* Hexagonal, usually the 6-sided prism with large terminal plane, with 6 and 12-sided pyramids on the intermediate edges, cleavage indistinct, parallel to terminal plane. Also granular, laminated. $H. = 9$. $G. = 3.6 - 4.1$, being greatest in the blue, least in the red. Color blue, red, yellow, brown, gray, white, the blue, often intense and pure; lustre vitreous; transparent, translucent; several varieties cut perpendicular to the axis exhibit an opalescent 6-angled star, when

COTTON.

compact, exceedingly tough, breaking with uneven, conchoidal fracture.

Chem. Relat. Unchanged alone, but dissolves slowly to a clear glass in borax and mic. salt, most easily dissolved by fusion with bisulphate of potassa. It is pure alumina Al_2O_3 .

Local. The blue or sapphires are found in Ceylon and other places in East Indies; St. Gothard, &c., in Europe; in U. S. Newton, N. J., Warwick and Amity, N. Y., West Farms, Conn.; of a fine hue from Delaware and Chester Cos. Penn. The red or rubies occur in the Capelan Mtns., Ava.; Bilin and Mero-witz, Bohemia. More common varieties are rather abundant in various localities.

Use. From its beauty of color, hardness, high polish, and variety, it is one of the most highly valued gems, a single specimen of the ruby having been sold for \$15,000. The common emery sand, powdered and washed over, is employed for cutting and polishing gems.

CORYDALIS TUBEROSA. *Fumaria bulbosa.* Analysis of the dry root by Wackenroder.

Albumen	1.84
Malate of <i>corydalin</i> , syrup and chloride of potassium	17.78
Starch	21.10
Green resin and fatty matter	0.81
Gum, malate of lime, and sulphate of potassa	9.21
Woody fibre	49.20
	99.84

Corydalin. From the *Corydalis tuberosa*, *Fumaria cava*, and *Corydalis fabacea*. Symb. $C_{34}H_{22}NO_{10}$ (?) Is without odor and taste. Dissolves in strong alcohol, from which, by spontaneous evaporation, it falls in crystallized plates. It is soluble in ether and partially so in hot water, and with the acetic and sulphuric acids forms crystallizable salts. The hydrochlorate uniting with the bichloride of mercury, gives rise to an insoluble double salt. *Winkler.*

COSMETICS. *Tech.* Preparations used for beautifying and preserving the skin, hair, and teeth; are so called from the Greek word κοσμέω, I adorn. Pomades, dentifrices, depilatories, and hair dyes, all comprised under this head, are fully treated of in *Celnart and Morfi's Manual of Perfumery*. See also *Pereira*, vol. i. p. 210.

COTARNIN. See NARCOTIN.

COTTON. *Syn.* Cotton Wool. *Ger.* Baumwolle. The filamentous down enveloping the seeds of the several species of *Gossypium*, belonging to the natural order of the *Malvaceæ*. In its natural state, after having been separated from the seeds by a gin, it is called raw cotton. Of this there are different varieties, each deriving its name from the locality of cultivation, and one of them, the Nankeen, having a dark yellow shade. In commerce the length and strength of the fibre regulates the classification into the long and short stapled. Cotton is largely cultivated in our Southern States and in the East and West Indies, but is indigenous to Asia and Africa.

Prop. Its formula is $C_6H_5O_5$. (*Payen.*) It is tasteless and inodorous, insoluble in wa-

ter, alcohol, ether, oils, and the vegetable acids, but is decomposed by the mineral acids, the nitric transforming it into *oxalic* acid by the aid of heat. Weak alkaline solutions do not affect it, but when boiled with those which are concentrated it is dissolved. Chlorine bleaches it, but slightly weakens the fibre. By distillation, a large amount of acidulous water and a little oil passes over, but no ammonia is formed. Its general and essential characteristics prove it to be identical with lignin ($C_{12}H_8O_8$), slightly modified.

Its affinity for alumina and other earthy and metallic oxides gives great facility in imparting color to it. (See DYEING.) Its almost exclusive use is for domestic purposes, as material, when woven, for dress; and in the arts, as the basis of paper.

As a means of detecting its admixture in white linen fabrics, Böttger proposes the use of a solution of equal parts of caustic potassa and water, which produces at $212^\circ F.$ a very decisive yellow coloring of the linen fibre, while the cotton remains nearly colorless, or so slightly tinged that the difference is unerringly perceptible. The tested sample must be unravell'd after the process, and examined by threads, instead of in the piece.

Cotton seed, when expressed, yields an unctuous oil, which is said to be an advantageous substitute for whale and linseed oils, but no accurate examination of its properties has yet been made.

Gun Cotton. This fulminating substance, of which, by reason of its filamentous structure and ready combustibility, cotton is the basis, was first practically applied by Schönbein. The priority of discovery is contested by other chemists, but as the identity of their fulminates with that of the former chemist is by him disputed, the contest is still open for decision. One thing is certain, Schönbein is the first who proposed it as a substitute for gunpowder.

Prep. Cotton cleansed and free of grease is immersed in a mixture of equal parts of concentrated nitric (spec. grav. 1.50), and sulphuric acids (spec. grav. 1.80). To prevent any danger of accident, none of the cotton should protrude above the level of the liquid. Whilst drying, and especially when still moist, care must be taken that the temperature does not exceed $212^\circ F.$ After being saturated, and after it has assumed an opaque, white appearance and lost its elasticity, which it does in a few minutes, it is to be taken out and placed upon a stone cullender, and washed under a tap with running water until all trace of acid is removed. (Washing with a saturated solution of nitre, it is said increases its explosive energy, and lessens the product of nitrous vapor on explosion.) Finally, press the cotton in a linen cloth, spread it upon frames, and dry it in a warm apartment. If the nitric acid be as weak as 1.36, the cotton is transformed into a gelatinous mass and failure ensues. Highly concentrated nitric acid will alone produce a highly explosive cotton, but the sulphuric assists by its presence in abstracting the water of the nitric acid. In appearance gun cotton differs nothing from ordinary raw cotton, but it is a little harsher to the touch.

Prop. Its explosive force is, by Prelat's experiments, 4 to 1 of gunpowder, weight for weight. According to Arago, the relation is as 1 to 3. Prelat's results have been partially confirmed by those of Capt. Mordecai, U.S.A. The chief disadvantage to its prevalent use is its bulk, and the difficulty and danger of manufacturing and transporting it. The large quantity of water, too, and the gases eliminated on deflagration, are more or less corrosive of the guns. The mode of charging is as with gunpowder, but its compressibility being greater, it occupies a smaller space. Friction which produces a temperature less than its point of ignition, does not inflame it. Concussion ignites the part immediately struck, but scatters the surrounding portions unchanged. These are the declarations of Capt. Susans of the French artillery, and Mr. Taylor adds, that it is inflammable at a heat much lower than is required for gunpowder.

In regard to the differences which have been noted by various chemists, as to the explosive force of gun cotton in fire-arms, and also to the temperature at which the explosion occurs, Vanckerknoff attributes it to the mode of drying, and especially to the greater or less rapidity with which the heat is raised during the process. For example, some gun cotton, when heated quickly in a glass tube over an oil bath, exploded just at 270° ; whereas, by raising the temperature gradually, 356° , and even 392° were attained without explosion. The reason is a modification of the original substances, by a continued heat of 302° . It is converted into tinder, with the loss of either nitrous or nitric acid or deutoxide of nitrogen; perhaps, says that chemist, it may be transformed into *Xyloidine*. At 356° the substance becomes yellow, and leaves a considerable carbonaceous residue on combustion.

The opinion advanced by Crum as to a mechanical union of the nitric acid with cotton, has been controverted by Tesschermacher and Porret, whose experiments prove it to be a strictly chemical compound of nitric acid and lignin, and as deduced from synthetical experiments, thus formed.

39.25 of cotton deprived of its constitutional
60.75 of nitric acid. [water.

100.00 and agreeing closely with the formula

$3C + 2O + 2H + N + 5O =$ nitrated cotton.

The analytical results of these chemists have confirmed the above, which, in centesimal proportions, may be expressed as follows:

Lignin dried.		
Carbon.....	20.00	} or (at 350°40 pts. nitric acid. 60 pts.
Oxygen { 17.78 { 44.44	62.22	
Hydrogen	2.22	100 pts.
Nitrogen	15.56	—
100.00		

The near agreement with the synthetical results establishes this as the composition of nitrated lignin.

In reverting to the gaseous products of gun cotton obtained by heat, they give as their composition when collected

Carbon	{	in the gases.....	15-03	}	= 22-738	
		in the anhydrous oxalic acid.....	2-708			
		in the residue....	5-000			
Oxygen	{	in the gases.....	31-680	}	= 54-876	
		in the water.....	17-780			
		in the oxalic acid.	5-416			
Hydrogen, in the water.....				2-220		
Nitrogen, in the gases.....				17-840		
						97-674

There is a deficiency of 2-326, arising from unavoidable errors and difficulties in experimenting necessarily upon very small portions and in multiplying, when brought out by calculation as 100 grains. The ultimate elements, compared with those of nitrated lignin, show the following near approximation.

	From the Analysis.	From the Composition of Nitrated Lignin.
Carbon.....	22-738	20-000
Oxygen	54-876	62-220
Hydrogen	2-220	2-220
Nitrogen	17-840	15-560
	97-674	100-000

Among the gaseous products there is doubtless a cyanogen compound, for this fact, first presented by Porret, has been sustained by the experiments of Dumas, Fordos, and Gelis. Viewing the composition of gun cotton in accordance with the ultimate results, by arranging the elements differently, and subtracting 1 atom of oxygen from the nitric acid, and adding it to the lignin, it would then be formed of nitrous acid and oxide of lignin. Upon this rationale Mr. Porret based the supposition of the presence of a new oxide with alkaline properties, and the idea being confirmed by the non-acidity of gun cotton, experiments were instituted with a view to the elucidation of the matter. Galvanic action of 48 hours' duration, eliminated from gun cotton, moistened with acetic acid, and placed between a plate of silver and zinc, a starchy looking substance, with an eminent power of blueing reddened litmus paper; and which, when heated to redness, left a black carbonaceous residue. Having succeeded in procuring it in a larger quantity by chemical means, he has announced it under the title of *Ligneæ*, which, when neutralized by hyponitric acid, precipitates from solution as hyponitrite of oxide of lignin, identical with gun cotton. *Ligneæ*, therefore, must be lignin and 2 atoms of oxygen, given by the nitric acid in becoming hyponitrous.

Porret suggests the probable origin of this alkali from the natural decay of woody fibre; and considering it in combination with acetic acid, so formed, also infers its existence in vegetable sap, where, by deoxidation and decomposition by light acting on the bark and leaves of plants, it is transformed into lignin by assimilation for the growth of the plant.

Schönbein undoubtedly, as Dumas admits,

deserves the honor of having been the first to show that the products of the action of nitric acid upon lignin are superior in explosive energy to gunpowder; but it must be recorded, that as far back as 1832, Robiquet produced an insoluble powder, explosive when heated, by the addition of water to a solution of saw dust in strong nitric acid. A year following, Braconnot discovered a similar amorphous pulverulent body, which he called *Xyloidin*. Water precipitates it from a solution of starch made in the cold, or from one of cellulose, effected at a higher temperature. Pelouze, in 1838, following out the investigation of the above two chemists, after describing the *xyloidin* of Braconnot as combustible and ignitable at 356° F., and as burning with vivacity and without residuum, announced that lignin, linen, or paper, when saturated with nitric acid, of spec. grav. 1-5, became extremely combustible; and now declares that as all kinds of cellulose produce like results with nitric acid, they are identical with gun cotton. *Azotic* paper, according to Pelouze, when well prepared, has an equally effective projectile power, and, in combustion, diffuses no nitrous (corrosive) vapor, and leaves no residue. Schönbein refutes this claim of priority, by asserting that his gun cotton is different from Braconnot's and Pelouze's *xyloidin*, in being insoluble in acetic acid. Without adopting the hypothesis of either, we will merely say, that the identity of *xyloidin* with *pyroxylin*, is denied by the discoverer of the latter substance.

According to Pelouze the *xyloidin* of Braconnot contains less oxygen, and consequently less nitric acid, than his product of 1838, and which he calls *Pyroxylin*, and he makes a distinction between it as the product of monohydrated nitric acid upon ligneous substances, without occasioning their solution, or rather that of the cellulose and the *xyloidin*, as a precipitate from the nitric solution of starch and lignin. He cites, in proof of his position, the insolubility of the former in nitric acid, whilst the latter is not only solved by it, but is subsequently decomposed and transformed into a deliquescent acid which he described many years ago.

Assuming, then, for convenience of explanation, the identity of gun cotton with *pyroxylin*, there are 175 parts produced by every 100 parts of pure cellulose dried at 300° to 320° F., and immersed in a mixture of monohydrated nitric, and sulphuric acids. A second immersion does not give an increase of weight, for the cotton is converted into *pyroxylin* instantaneously, and the only products of this action are water and *pyroxylin*, and the latter, when dried between 104° and 130°, is unaltered; but near to 212° gradual decomposition ensues with the disengagement of nitric acid odors, there being produced by an hour's continuance of the temperature between 212° and 220°, a loss of 10 pr. ct. in weight of the original body, which becomes yellow, friable, and prone to frequent and sudden ignition.

Pelouze, with full confidence in the accuracy and uniformity of his analyses, confirmed by frequent repetition, opposes the formula as-

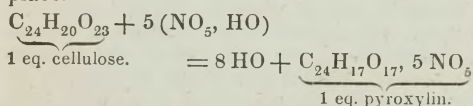
COTTON.

signed to pyroxylin by Pelijot, who asserts that in the transformation cotton loses 1 eq. of water, and combines with 3 eqs. nitric acid, and on its decomposition yields 9 CO, 3 CO₂, 3 N, and 9 HO.

To sustain himself, he gives as the accurate composition of nitrate of cellulose:

	Minimum.	Maximum.		
Carbon	25.2	25.8	24	25.40
Hydrogen	2.9	3.2	17	2.99
Nitrogen	12.6	13.0	5	12.34
Oxygen	—	—	42	59.27

This composition supposes that 100 parts of pure, dry cotton should yield 174.9 pyroxylin; Pelouze found from 174 to 176, and in order to check the preceding analysis taking Payen's formula of cellulose, C₁₂H₁₀O₁₀, which he found correct by actual analysis of a portion of that to be converted, and doubling it in order to represent one equivalent of cellulose, he shows, as follows, the equation by which the conversion into pyroxyline would take place.



Five eqs. of nitric acid in acting upon one eq. of cellulose would give rise to 8 eq. of water and 1 eq. of pyroxylin; of these 8 eqs. of water, 3 would be furnished by the organic substance, and 5 from the monohydrated nitric acid. The rapid weakening of the concentrated acids is thus accounted for in the elimination of so large a quantity of water.

The formula for pyroxylin, C₂₄H₁₇O₁₇, 5 NO₅, explains why this explosive substance leaves no carbonaceous residue upon combustion. Indeed its complete transformation into elastic fluids and aqueous vapor is possible, for, independent of nitrogen and the elements of water, it contains 24 eqs. carbon to 25 eqs. of oxygen,—more than sufficient to oxidize the whole of the carbon into CO.

The products of the detonation of pyroxylin are given in the table below. The sum equals one equivalent of pyroxylin, as represented by Pelouze's formula, but the numbers are purely theoretical, and must necessarily be modified by a number of circumstances, the most important of which are the greater or less temperature, and the degree of pressure at which the inflammation occurs.

46 vols. of carbonic oxide.....	C ₂₅ O ₂₃
2 " " acid.....	CO ₂
10 " " nitrogen.....	5 N
34 " " aqueous vapor.....	17 HO.

Ransom, who has also investigated the subject, gives C₁₂H₈O₂₀N₂, as the formula of gun cotton. Now if this be correct, the transformation of the raw cotton is effected by the abstraction of 2 equivs. of hydrogen, and the addition of 3 equivs. of nitric acid, and consequently its explosion would generate 12 equivs. carbonic oxide, 8 equivs. of water, and 2 equivs. of nitrogen.

Pelouze and Ransom's products of detonation would create an inevitable corrosion of

COUZERANITE.

the metal of the guns, but Dumas says that the gaseous results produced under the pressure of the projectile in a narrow space, where for some time the inflammable gases and nitrous vapor, strongly heated, may react together, differ from the acid products eliminated by ignition in the open air. So, accordingly, the inferred injury to fire-arms should not result, yet it does take place, as Capt. Susans' practical experience has proved.

Vanckerknoff proposes to distinguish cotton from pure pyroxylin of any ligneous substance, by treating each with sulphuric acid of 1.80 to 1.70, and subsequently heating them over a water-bath. A more or less decided coloring indicates the presence of cotton even before the bath has acquired a temperature of 196° F., whereas, pyroxylin merely disengages gas without tinging the solution. During the reaction of sulphuric acid upon the pyroxylin, carbonic acid and deutoxide of nitrogen are generated among other gases, and an organic substance, apparently with but little carbon, and which is not cellulose, remains in solution.

As a substitute for the detonating compound used in percussion caps, the filamentous pyroxylin does not answer so well, without an addition of small portions of powder to perfect its combustion, but made of compact tissues of cotton or linen, according to Pelouze, it detonates when struck as violently as fulminating mercury.

Bizard's *chlorated lignin*, made by impregnating raw cotton or sawdust with chlorate of potassa, is equal, if not superior, in fulminating power to gun cotton. Forty to fifty milligrammes produce an effect, in its discharge from a pistol, which would endanger its bursting if the quantity be increased. Paper pyroxylin moistened with solutions of nitrate of strontia, sulphate of copper, and nitrate of baryta, yield beautiful red, green, and white fires. The impediment to rapid combustion, produced by solutions of metallic salts, favors the duration of its effects, and renders paper, thus prepared, a useful material in pyrotechny.

COTUNNITE. *Min.* It occurs in soft, white, acicular crystals, of an adamantine lustre, which on charcoal readily fuse, burn with a blue flame, evolving much white vapor, which condenses on the charcoal, and leaving a little metallic lead (much more with soda); in a closed tube it fuses, becoming yellow, and sublimes; soluble in hot water. It is chloride of lead, PbCl, and was found in the crater of Vesuvius.

COUMARINE. *Chem.* See **TONKA BEAN.**

COURT-PLASTER. *Tech. Syn. Emp. Adhesivum Anglicum.* Is made by stretching silk upon a frame, and brushing it over several times successively with a warm mixture of tincture of gum benzoin and a thick solution of isinglass. When perfectly dry, a finishing coat of 6 oz. chian terpenine, dissolved in tincture of benzoin, must be applied in order to prevent its cracking.

COUZERANITE. *Min.* Rhombic prisms, of a grayish or black color, vitreous lustre. H. = 6 — 6.5. G. = 2.69. It fuses to a white

CRAJURU.

enamel with mic. salt to a white glass. Form. $\text{CaO}, \text{SiO}_2 + 2(\text{Al}_2\text{O}_3, \text{SiO}_2)$. The lime contains also magnesia, potassa, and soda. V. Kobell thinks it belongs to Labradorite. It occurs at Couzeran, in the Pyrenees.

CRAJURU. *Tech.* Syn. Carajuru, Carucuru. A new, red, tinctorial substance, imported from Para, in Brazil, analogous to *Chica*, but of a more brilliant vermilion-like hue. According to Boussingault and Rivero, it is useful as affording a rich, beautiful dye. It is in light inodorous, slightly bitter pieces, of an intense violet, coppery lustre, when rubbed against a hard body. Though insoluble in water, it is readily taken up by alcohol, ether, and the oils, and from its alkaline solutions is precipitated by dilute acids, nearly unaltered in color. It is a product of the *Bignonia Chica* and other species of the Bignoniaceæ, from Equinoctial America. *J. J. Virey.*

CRAMERIA. Syn. Rhatany; *Krameria triandra*. A South American plant, the root of which is a powerful tonic astringent, and composed, according to Peschier, of

Dried watery extract 31.25
Insoluble matters 68.75

Rhatany root 100.00

The dried watery extract contained

Tannin 42.6
Gallic acid 0.3
Gum, extractive and coloring matter 56.7
Krameric acid 0.4

100.0

Its styptic properties are attributable to the *krameric acid*, ($\text{C}_{10}\text{H}_8\text{O}_5$), which is not volatile, crystallizable, and forms crystalline salts by union with bases; of these the kramerate of baryta is most characteristic, being soluble in 600 parts boiling water, not precipitable by sulphuric acid nor a sulphate, but by a carbonate. The acid even separates sulphuric acid from the sulphate of baryta.

CREAM. *Tech.* A term given in several instances to articles of the toilet, in consequence of their cream-like consistence and appearance, but properly belonging to and almost exclusively applied to the oleaginous yellowish white stratum which collects upon MILK that has stood for some hours. The chief constituent of cream is BUTTER, but as there is always more or less of milk admixed with it, a particular action is requisite for its separation, and this is agitation, or churning, which by transforming the saccharine components of the latter into lactic acid, coagulates its limited portion of CASEIN, and eliminates the butter in flocculæ, which, rising to the surface, conglomerate, and leave the other components either solved or suspended in the buttermilk. The incipient acidity, generated in cream by exposure, renders sour cream more favourable for churning than that which is recently formed.

CREAM OF TARTAR. See TARTARIC ACID.

CREASOTE. *Chem.* Syn. Creosote, Kreosote. Obtained by Reichenbach as a product

CREASOTE.

of the destructive distillation of wood; and so called from *κρέας*, flesh, and *σῴζω*, to preserve, by reason of its antiseptic properties, due to its power of coagulating albumen, and rendering flesh insusceptible of putrefaction. It is a highly refractive, colorless liquid, of spec. grav. 1.037 to 1.060. Boils at 397° , and remains fluid even to 16.6° . Applied to the skin, causes a white spot, and disorganizes the cuticle without producing inflammation.

Properties and behaviour. Form. $\text{C}_{14}\text{H}_{16}\text{O}_2$. Is soluble in alcohol, ether, eupione, oil of petroleum, and acetic acid. Eighty pounds of water, at a medium temperature, dissolve one part of creasote;—the resulting liquid being perfectly neutral, and from its property of precipitating albuminous solutions, has been sold under the names of *Eau de Brochieri* and *Aqua Finelli*. Potassa transforms it into two compounds;—an oily, anhydrous liquid, and a white, hydrated body, in crystallized deliquescent pearly plates, both of which are readily decomposable by the acids. (*Graham.*) Soda operates similarly to potassa. With lime and baryta, by the intervention of water, creasote forms unctuous compounds which become, by exposure, hard, pulverulent, and insoluble in water; sulphuric acid added to a concentrated solution of creasote in potassa, creates the double salt, *sulphate of potassa and creasote*. United with chlor-calcium the compound resists the decomposing power of heat. Nitric acid, after a lively action, resinifies creasote, and when concentrated produces an explosion.

Chlorine develops hydrochloric acid and thickens the creasote. Bromine acts energetically, and iodine forms a red, brown liquid. Sulphuric acid in the cold changes it to red, purple, and finally to deep red. Water added to the red liquid dissolves out an acid, which, with baryta and oxide of lead, forms soluble, non-crystallizable salts. (*Gerhardt.*) If the sulphuric acid is hot, the mixture becomes black, and sulphurous acid is disengaged. Potassium is converted into potassa, with effervescence. Binoxide of mercury, when heated with creasote, is reduced to metal.

Among the many organic substances which creasote dissolves, are indigo, camphor, and resins.

Passed in vapor through a hot tube, it is decomposed into naphthalin, a sebaceous substance, and an inflammable, non-fuliginous gas, and plates of graphite-looking carbon, which are deposited in the tube.

According to Deville, the *hydruret of guaiacyle*, ($\text{C}_{14}\text{H}_{16}\text{O}_4$), formed by the distillation of guaiacum resin, so nearly resembles creasote ($\text{C}_{14}\text{H}_{16}\text{O}_2$) that it may be considered as its oxide. The same chemist regards creasote as the alcohol of the benzyl series, and as ranging in the class of essential oils regenerated by distillation. *Ann. der Chim. und der Phys.*, xii., p. 228.

Laurent calls the products of the oxidation of creasote, *creasotic acid*. When creasote is treated with chlorate of potassa and hydrochloric acid, *chloranil* is formed in yellow laminæ; and the action of nitric acid, and subsequently of ammonia and alcohol, produces *nitrophenissic acid*, in six-sided prisms, and two

other acids, one of which is in long, yellow laminæ, and the other in minute needles. *Comptes Rendus*, xix., p. 574.

The great similarity of creasote to carbolic acid or hydrate of phenyl, ($C_{12}H_9OHO$), in many respects renders it probable that it is either that body contaminated with foreign matter, or that the two are closely connected and belong to the same series, which is that of benzyl or that of phenyl. *Turner*.

CREATIN. *Chem.* When crystallized its formula is $C_8N_3H_{11}O_6$. (*Liebig*.) A neutral body, discovered by Chevreul, and supposed to exist in the flesh of all classes of animals. Dissolved in weak alkaline or acid liquids, no alteration ensues, but when concentrated, these reagents alter its properties,—the strong acids converting it into a remarkable organic base, which Liebig terms *Creatinin*, ($C_3N_3H_7O_2$). This base is more soluble in water and alcohol than creatin, and with the acids it forms salts of great beauty. The crystals of creatin are bulky, colorless, and lustrous. By long continued boiling with very concentrated barytic water, creatin is decomposed into urea and a new organic base and acid, which is crystalline. *Comptes Rendus*, 1847.

CRENIC ACID. See HUMUS and MOULD.

CRICHTONITE. See TITANIC IRON.

CRISPITE. See RUTILE.

CROCALITE. See MESOTYPE.

CROCIDOLITE. See KROKIDOLITE.

CROCOISITE. See CHROMATE OF LEAD.

CROCONIC ACID. See RHODIZONIC ACID.

CROCUS OF ANTIMONY. See ANTIMONY (OXYSULPHURET).

CROCUS MARTIS. See IRON, Oxide, and COLCOTIAR.

CROCUS SATIVUS, or ORIENTALIS. See SAFFRON.

CRONSTEDTITE. *Min. Syn.* Rhomb. Melane-mica. *M.*; Chloromelan. *Descrip.* Cryst. Hexagonal prisms, cleaving perfectly parallel to terminal plane; also diverging, reniform, amorphous. $H.=2.5$. $G.=3.348$. Brownish black, opaque, brilliantly vitreous, thin laminæ, elastic, not brittle, with dark green streak. *Chem. Relat.* In a closed tube gives water and traces of fluoric acid; alone it froths and fuses partially to a dull, black glass; with the fluxes gives the reactions of iron and manganese, with soda a black glass, with more soda still fusible and entering the charcoal, soluble in chlorohydric acid and gelatinizes. Formula $3FeO, SiO_2 + Fe_2O_3, 3HO$, the FeO being partly replaced by magnesia and manganese. *Local.* Przibram, Bohemia; Wheal Maudlin, Cornwall; mines of Conghonas do Campo, Brazil.

CROSS-STONE. See STAUROTIDE and HARMOTOME.

CROTON OIL. *Phar. Chem. Syn.* *Tiglin Oleum* (Lat.). Is expressed from the seeds of the *Croton tiglium* tree, native to Ceylon and the Molucca Islands, and hence their other name of *Molucca grains*. Is of an amber color, acrid taste, and unpleasant odor, and soluble in alcohol. The oil of the *Croton pavana* is darker, thicker, and less energetic than the above. (*Pereira*.) The acrid matter, separable from the oil by alcohol, consists of resin (?)

Crotonic acid, and a peculiar alkaline principle, *crotonin*, which is insoluble in water, but crystallizes from its solution in alcohol. With sulphuric and other acids it forms crystallizable salts.

Crotonic Acid. *Syn.* Iatrophic acid. An acrid, highly poisonous, volatile acid, obtained by saponifying the croton oil, decomposing the resultant soap, and distilling the product. As thus procured is a nauseous smelling liquid, capable of uniting with bases to form crystallizable salts.

CROTON ELEUTHERIA. See CASCARILLA.

CRUCIBLE. *Chem. Tech.* A vessel in which bodies are exposed to high temperatures, usually in the form of an inverted and truncated cone. In the laboratory of the chemist they are made of various materials, platinum, porcelain, clay, graphite, or charcoal, according to the object in view.

For analytic research the *platinum* crucible is almost indispensable, since that metal is tough, bears the highest temperatures without fusion, and is not injured by a large number of chemical agents. The form of these is given in figs. 21, 22, pp. 172, 173, under ANALYSIS, where the mode of employing them for burning off filters, &c., is given in some detail.

For fusion, and higher or more rapid heats, the Table BLOWPIPE is more convenient, the jet of which passes through an argand burner for gas, or for a solution of spets. terpentine in alcohol. For convenience in evaporating, Berzelius employs a crucible with a wider opening, but it is better to have a shallow dish of platinum for this purpose, in addition to the crucible, similar to fig. 11, p. 169.

In Analysis. Much care is requisite in the use of a platinum crucible. Caustic fixed alkali, nitrates of alkali, or alkaline earths, when fused in it, always attack the platinum. Alkaline sulphurets, or sulphates with charcoal, injure it still more. Phosphorus, or phosphoric acid and carbon readily attack it. Metals alloy readily with platinum, when heated in it near to their fusing points, and hence the great danger of lead, tin, antimony, &c., being heated even moderately in it. Even their oxides, especially those of lead, bismuth, copper, and nickel, reduce at a high heat by contact with platinum, the two former at a lower temperature than the latter; much more readily does reduction follow if charcoal be present. Sulphate of lead may be burned off in it with care. Although silica may be ignited to a full, red heat in platinum, yet it combines at a higher heat with silicium, even abstracting it from coals; it should therefore never be placed in immediate contact with ignited coals, but put into a clay crucible on a bed of calcined magnesia. In general, all liquids may be evaporated in platinum, except they contain chlorine or bromine. When it becomes internally stained, it may be cleansed by sand or fine pumice and water, or by fusing borax in it. When it becomes cracked or alloyed with any of the above substances, except a noble metal, it may be repaired by welding on a layer of platinum sponge, but it is far better to fuse it by the

hydroxygen blowpipe and remodel the crucible.

Porcelain crucibles, when small and very thin, like those made in Berlin, may often, and must sometimes, be substituted for platinum, although they are liable to crack by too rapid cooling. Berzelius inserts them in a platinum crucible, whereby their frangibility is diminished. Where bodies are to be heated in furnaces, coarser crucibles are employed. Among the most celebrated are the *Hessian*, made from clays of Hirschberg, Grossalmerode, Hessia, which have not been equalled for cheapness and other qualities combined. But each chemist may make refractory crucibles of a fire-clay, by burning a portion of the same, pulverizing it, and mixing it with the unburned clay and a little water to a very stiff mass. A thorough beating of the mixture is requisite to render it homogeneous and remove all air-pores, and its quality improves by keeping weeks or months. This mass is then driven by a steel pestle, the lower part of which has the exact form of the interior of the crucible, into a steel or cast-iron mould of the form of the outside of the crucible. The pestle and mould having been oiled to prevent adhesion, the crucible is removed from the mould, air-dried, then warmed, and may or may not be ignited previous to use. Such *Hessian* or clay crucibles are now less employed by the theoretic chemist than formerly, but are still indispensable in metallurgic operations, and in alkaline fusions. It is usual, and in general better, to employ a new crucible for each operation. For larger crucibles of this kind see GLASS, POTTERY.

A very serviceable crucible for metallic reduction on a small scale is afforded by the charcoal or brasqued crucible, which is made by stamping powdered and sifted charcoal, scarcely moistened with water, layer by layer, into a *Hessian* or other clay crucible, until the whole is filled, and then boring out of the solid bed a cylindrical or conical opening, into the bottom of which the metallic compound with its flux is introduced, and the remainder filled up with the charcoal slightly pressed down.

Black-lead crucibles, largely employed in the arts for metallic fusion, are made of a mixture of graphite (plumbago) and clay, in the varying proportion of 2, 3, 4 pts. of the former to 1 pt. clay. They bear a very high heat, comparatively sudden changes of temperature, and have a smooth surface, but salts attack them, and hence their exclusive use for melting metals.

CRUCITE. See ANDALUSITE.

CRYOLITE. *Min.* Cryst. Right Rhombic, prismatic, with perfect basal cleavage. $H.=2.25-2.5$. $G.=2.949$. White, sometimes reddish or brownish; vitreous; subtransparent, translucent; brittle, with white streak. Very fusible into a white enamel, fusing in a candle-flame; gives the reaction of fluorine in an open tube; very soluble in the fluxes, almost wholly soluble in oil of vitriol, less so in muriatic acid. Form. $3 NaFl + Al_2Fl_3$. It occurs at Arksut-fiord, Greenland.

CRYOPHORUS. *Phys.* *Kroc, frost*, and *peg, I bear*. Invented by Wollaston. A glass

tube freed from air, with a bulb at each end, for illustrating the freezing of water by its own evaporation. One of these bulbs contains pure water, and the rest of the apparatus aqueous vapor. The resistance or presence of the latter being removed, when condensed, by immersing the bulb which holds it in a freezing mixture, a rapid evaporation from the surface of the water in the other bulb immediately ensues, and results in an intensity of cold, which causes the freezing of the residual water in a few minutes.

CRYSTALLIN. The same as KYANOLE and Anilin. See INDIGO and TOBACCO.

CRYSTALLIZATION. The formation of crystals, for which purpose it is essential that the particles of the crystallizing substance have more or less freedom of motion, when they arrange themselves in determinate positions by the influence of a variety of cohesive force. Bodies usually crystallize from solution, sometimes after fusion, by sublimation, and rarely while in the solid state. It is not material what the solvent may be, although it probably influences the external form, whether water, acids, alcohol, ether, sulphuret of carbon, &c., provided the substance dissolve in it. To obtain crystals the usual method is to dissolve in the hot solvent, which holds more in solution than the cold, and to let the excess crystallize out on cooling, Saltpeter, Alum; or, during evaporation, Common Salt. A solution is sometimes evaporated nearly to a syrupy consistence before the substance separates from it, as Sugar, Epsom Salt. As solutions are usually made in smooth-surfaced vessels, which retard crystallization, the introduction of twine, or a rough-surfaced body, will determine a more rapid separation of crystals. To obtain them with more perfect faces, the crystallizing solution should not be disturbed, and the evaporation should be carried on slowly. Spontaneous evaporation generally produces the best results. Small-sized crystals may be often enlarged by introducing them into another solution of the same body ready to crystallize. The mother-liquor, often impure, is enclosed in larger crystals in a greater or less degree, and in order to obtain purer crystals from such a solution, it should be stirred or agitated during crystallization, whereby the substance separates in a fine fibrous or granular powder. Where a body is precipitated from a solution by reason of its insolubility, the precipitate is usually crystalline, when viewed by a microscope; and hence such substances, when found in the mineral kingdom, are usually more perfectly crystallized, having been elaborated by time, so important an element in the construction of regular forms; as Carbonate of Lead or of Lime, White Lead, or Calcareous Spar.

Some metals separate in crystals from solution by the introduction of another metal, which replaces the former in the solution; as lead or silver separated from their solutions by zinc. In like manner the native crystals of Copper, Gold, and Silver have been produced. A galvanic current often separates bodies in a crystallized form from solution, and probably by a similar action, or by one like the

preceding, large formations of metallic sulphurets have been produced, as Galena, Pyrites.

Some bodies are obtained in a crystalline form by fusion. If sulphur or bismuth be fused, then allowed to cool until the surface congeals, this crust broken through, and the interior still fused mass be poured out, the interior cavity will be found coated with crystals. Some salts also undergo fusion, whether water be present or not, and exhibit on cooling, crystallized forms or crystalline structure; as Saltpeter, Glauber's salt; but in the latter case a portion of water is lost and a new hydrate formed.

Bodies, which sublime with little or no decomposition, condense in crystals from their vapor, as Sulphur, Galena, Arsenic, and many organic bodies. Some bodies are capable of crystallizing by several methods, as Common Salt, which crystallizes from solution, by fusion and by sublimation.

A few instances have been observed, where a body still retaining the solid state, assumes a crystalline structure by the effect of heat and agitation, whereby the particles of the body have received sufficient motion to allow them to obey the crystalline forces. The wrought-iron axles of railroad cars, after long use, are sometimes found to present a decided crystalline structure. When some kinds of glass are maintained at a high heat, they assume a crystalline structure; Reaumur's porcelain.

Water of Crystallization. Bodies separating in crystals from an aqueous solution, often assume a portion of water essential to their constitution; but the quantity of crystal-water varies with different salts; thus while saltpeter has none, Glauber's salt has 56 pr. ct., or 10 equivs. of crystal-water.

Some bodies crystallize in more than one form, and are called dimorphic. See DIMORPHISM. Different bodies may replace each other in the same form of crystal. See ISOMORPHISM. See also DELIQUESCENCE, EFFLORESCENCE.

CRYSTALLOGRAPHY. *Chem. Min. Physics.* A crystal (from κρυσταλλος, ice), is a solid, bounded by plane surfaces, symmetrically arranged, with an internal symmetric structure. It may be an element or a compound body, and in the latter case the elements are

always combined in definite chemical proportions. The measurement of corresponding surfaces is always the same in the same substance, and all the varieties of form in the same substance may be reduced to one of six elementary forms, by calculation or by cleavage. *Cleavage* is the property possessed by most crystals of being broken in determinate directions, presenting new plane surfaces, usually polished, whereby a more simple form is often obtained, denominated the *primary form*. Thus a cube of fluor-spar may be cleaved into an octohedron by cutting off its solid angles. This primary form was formerly laid at the basis of descriptions of crystals, but as more than one simple geometric solid may sometimes be obtained from the same substance, as there is frequent difficulty in obtaining cleavage at all, or only in one or two directions, and as there are usually assumed thirteen primary forms, we prefer at the present time the more simple reduction of all crystallized forms to six distinct systems of crystallization. The propriety of this division has been confirmed by their optical relations. We here offer a few remarks on these systems, and on their combination of simple forms under each.

Under each of five systems there are three axes, the relative lengths and position of which determine the system; under the sixth, four axes. Under the former, an octohedron is viewed as the basis, with the axes terminating in its tetrahedral angles; under the latter, an analogous figure, consisting as it were of two six-sided pyramids, united at their bases. Under each system there are a few simple forms, related by simple laws to the basis, by the combination of two or more of which, even the most complex forms of crystals may be explained.

Where one-half of the planes of a simple form disappear, a hemihedral or hemiform is produced, giving rise to two classes of forms, holohedral and hemihedral forms. A simple law of combination is, that all the simple forms of one system may combine in crystals belonging to that system, but the simple forms of diverse systems cannot combine.

The following table presents the *Systems of Crystallization*, with the names given by different authorities.

	Mohs.	Naumann and others.
Regular	Tessular	Isometric
Quadratic	Pyramidal	Dimetric
Right Rhombic	Orthotype	Trimetric
Oblique Rhombic	Hemiorthotype	Monoclinic
Doubly Oblique Rhombic	Anorthotype	Triclinic
Hexagonal	Rhombohedral	Hexagonal

I. Regular System. Three axes, equal, and at right angles to each other. A section at right angles to any axis is a square. There are 7 simple holohedral, and 6 simple hemihedral forms. *Holohedral forms.* 1. The regular octohedron, or 8-hedron, Pl. VIII., fig. 1, with 8 triangular surfaces, *o*, and a square section at right angles to any axis, as Spinel, Magnetic iron ore. 2. Regular or Rhombic dodecahedron, or 12-hedron, fig. 2, with 12 rhombic faces, *d*, as Garnet. If each edge of the 8-hedron be

supposed to be replaced evenly by a plane, it becomes a combination of the 8- and 12-hedron, fig. 3; as Garnet, Magnetic iron. Where the 8-hedron predominates, *d* forms a long, narrow plane on the edges of the 8-hedron; where the 12-hedron predominates, *o* forms a small triangular plane, fig. 3, on the trihedral angle. 3. The ikositetrahedron, 24-hedron, fig. 4, has 24 trapezoidal planes. There are two of these forms, one where any plane meets 2 axes at twice the distance from the centre that it

meets the 3d axis, $\frac{o}{2}$, fig. 4, as Leucite, (hence called Leucitöeder); Analcime, Garnet; the other meets 2 axes at 3 times the distance, $\frac{o}{3}$; as Gold, Silver. Fig. 5 represents a combination of the 12-hedron, d , and 24-hedron, $\frac{o}{2}$, as in Garnet; fig. 6, a combination of 8-, 12-, and 24-hedron $\frac{o}{3}$, Magnetic Iron. 4. The *hexakisoctohedron*, 6×8 -hedron, fig. 7, is rarely found alone, Diamond (!), but fig. 8 represents a combination of it with the 12-hedron, d , and 24-hedron, $\frac{o}{3}$, Garnet. The name 6×8 -hedron evidently denotes the resemblance of the figure to an 8-hedron, with 6 planes on each of its surfaces, but it may also be viewed as a hexahedron, with 8 planes on each of its surfaces, when it becomes an octakisexahedron, 8×6 -hedron. 5. The *hexahedron*, or *cube*, a , fig. 8, has 6 faces, its opposite ones parallel, with the axes striking the centre of each face, as Fluor spar, Galena, Common Salt. Hence, when combined, the 8-hedron, o , appears on its solid angles, o , fig. 8, as Galena, Fluor Spar; and the dodecahedron replaces its edges, d , fig. 9, which is a combination of all three, as Speisscobalt. By comparing figs. 4 and 8, the 24-hedron, $\frac{o}{3}$, would appear as 3 small planes on the solid angles of the cube, in place of the 8-hedral planes, o , as in Analcime; and, in like manner, the 6×8 -hedron would form 6 small planes in the same place on the cube, as Fluor Spar. 6. The *tetrakisexahedron*, 4×6 -hedron, fig. 10, may be viewed as a cube, (6-hedron), with a 4-sided pyramid on each surface; Gold, Copper; and in combination with the cube, bevels the edges of the latter; frequent in Fluor spar. 7. The *triakisoctohedron*, 3×8 -hedron, fig. 11, may be viewed as a triangular pyramid on each surface of the octohedron, and, in its combination, bevels the edges of the latter, as in Fluor spar.

Hemihedral Forms. 1. The *hemioctohedron*, $\frac{1}{2}$ 8-hedron, fig. 12, is formed by supposing every alternate face of the regular 8-hedron to disappear by the increase of the other alternate faces until they meet, and may be termed the tetrahedron. When held by the observer so that the upper right face remains, it is the right $\frac{1}{2}$ 8-hedron, or ; if the left remain, and the right disappear, it is the left $\frac{1}{2}$ 8-hedron, ol , as Gray Copper, Blende. The distinction between right and left is often convenient in describing combinations, where a right $\frac{1}{2}$ 8-hedron may be combined with a right or left $\frac{1}{2}$ 24-hedron, or some other hemiform. 2. When every alternate set of 3 planes in the 24-hedron, fig. 6, forming the low, 3-sided pyramid, remains, and the others disappear, the *hemi-icositetrahedron*, $\frac{1}{2}$ 24-hedron, $\frac{o}{2}$, is formed, fig. 13, of which there is a right or left, as Gray Copper. Fig. 14 is a combination of the 12-hedron, d , with the right $\frac{1}{2}$ 8-hedron, or , and $\frac{1}{2}$ 24-hedron, $\frac{o}{2} r$; Gray Copper. 3. Fig. 15 is the right *hemi-triakisoctohedron*, $\frac{1}{2} 3 \times 8$ -hedron, $2 or$, formed by every alternate set of 3 faces remaining in fig. 11. 4. There is likewise a *hemi-hexakisoctohedron*, formed by the disappearance of every alternate set of 6 planes, and found in combinations. 5. When every alternate set of 2 planes in fig. 7 remains, the *hemi-octakisexahedron*, $\frac{1}{2} 8 \times 6$ -hedron, is formed, fig. 16, of which there is a right and left;

Iron Pyrites. 6. The *hemi-tetrakisexahedron*, $\frac{1}{2} 4 \times 6$ -hedron, is formed by the disappearance of every alternate plane in fig. 10, and constitutes the pentagonal dodecahedron, or pyritohedron, fig. 17; Iron Pyrites, Cobalt Glance. Speisscobalt, Garnet, Magnetic Iron, and Fluor spar illustrate most of the holo-hedral forms; Cobalt Glance, Iron Pyrites, and Blende illustrate the hemiforms. Alum produces artificially a variety of combinations.

II. *Quadratic or Dimetric System.* Three axes, two equal, one unequal, and at right angles to the two equal axes. A section at right angles to the main axis is a square, to a lateral axis is a rhomb. Having one unequal or main axis, crystals belonging to this system are always viewed with their main axis vertical, and a lateral axis pointing towards the observer. A *quadratic 8-hedron*, fig. 18, is the basis, of which there may be several more obtuse or more acute than the radical 8-hedron peculiar to each substance. The main axis may be longer or shorter than the lateral axis, the latter being the case in fig. 18, and the former in fig. 24. Another simple form is the *4-sided prism*, which, when replacing an edge of the 8-hedron, is said to be of the first order, as in fig. 19; but if the solid angles, as in fig. 20, it is of the second order. Fig. 18 represents the radical 8-hedron, o , of Zircon, in which the main axis is shorter than the other two. Fig. 19 shows the same 8-hedron, o , of Zircon combined with the 4-sided prism, g , of the first order, *i. e.* exactly on the lateral edges of the 8-hedron, and fig. 20 the same 8-hedron with a prism, a , of the second order. Where the edges of an 8-hedron are evenly replaced by planes, these form its first obtuser 8-hedron, as in fig. 21, where o is the radical 8-hedron of Anatase, and d its first obtuser 8-hedron. Inversely if d were the radical, o would be the first acuter 8-hedron. Where a more acute or obtuse 8-hedron has its lateral edges parallel with those of the radical, it is of the 1st order, if it cleave the pyramidal edges, it is of the 2d order. Thus in fig. 22, Molybdc Lead, o is the radical 8-hedron combined with one obtuser, $\frac{o}{3}$, of the first order, with its first obtuser, d , and with the first acuter one, $\frac{2}{3} d$, of $\frac{o}{3}$. There is a *diotohedron* found in combination, differing from a combination of two 8-hedra of the 1st and 2d orders, by each alternate angle being more acute or obtuse than the intermediate angle. It has also a corresponding or *diotohedral prism*, and both prism and diotohedron may be of two orders. Thus in fig. 23, o is the radical 8-hedron of Zircon, with a 4-sided prism, a , of the 2d order, and the diotohedron, $3, 3, 3$. In fig. 24, o is the main 8-hedron of Apophyllite, a the 2d 4-sided prism, and $2g$ the diotohedral prism. There is also a *terminal* or *end-plane* at right angles to the main axis, as c , fig. 21. A combination of a 4-sided prism and end-plane would form a parallelopipedon. Hemihedral forms are rare. The hemi-octohedron is sometimes noticed in Copper Pyrites. The $\frac{1}{2}$ diotohedron is very rare.

III. *Right Rhombic or Trimetric System.* Three axes, all unequal, but at right angles to each other. A section at right angles to any axis

is a rhomb. It is immaterial which axis is held vertically, but the prevailing character of a substance is sometimes allowed to determine the vertical or main axis, relative to which the others are called lateral axes, the one pointing to the observer the 1st lateral axis, the other the 2d lateral axis. There are several 8-hedra, horizontal and vertical prisms, and terminal planes at right angles to each axis. If a horizontal prism meet the main and 1st lateral axis, it is called a 1st horizontal prism, if the main and 2d axis, a 2d horizontal prism. The terminating plane of the main axis is termed the end-plane, of the first lateral axis the 1st side-plane, of the 2d lateral axis, the 2d side-plane. Fig. 25 represents the radical 8-hedron, *o*, of sulphur, with an obtuser 8-hedron, $\frac{o}{3}$, the end-plane, *c*, and the 2d horizontal prism, *f*, of the main 8-hedron. Fig. 26 shows the vertical prism, *g*, of the radical of White Lead with the 1st and 2d horizontal prisms, $\frac{d}{2}$, and $\frac{f}{2}$, and with the 2d side-plane, *b*. Fig. 27 shows the same as fig. 26, but with a different 2d prism, $2f$, and the radical 8-hedron, *o*; Saltpeter. Fig. 28 exhibits the 2d prism, *f*, of the radical of Heavy Spar, with a 1st prism, $\frac{d}{2}$, and the end plane, *c*. Heavy Spar and White Lead present many varieties in the combinations of the prisms and terminal planes. Saltpeter exhibits forms like figs. 27, 28. Topaz often exhibits several vertical prisms. Fig. 29 shows a more complex combination in Chrysolite, consisting of the main 8-hedron, *o*, its vertical prism, *g*, and end-plane, *c*, its 1st horizontal prism, *d*, and a 2d horizontal prism, $2f$, and the 1st and 2d side planes, *a* and *b*. Sulphate of potassa presents a similar form. Hemihedral forms are very rare in this system.

IV. *Oblique Rhombic or Monoclinic System.* Three axes, unequal, two oblique to each other, the third at right angles to the other two. A section, parallel to the oblique axes, is a rhomboid, to the right-angled axis is a rhomb. Either one of the oblique axes being held vertically is oblique to the plane of the two others, which are at right angles to each other, and the longer upper edge of the 8-hedron is held towards the observer. As in the preceding system, therefore, there is a main axis and a first and second side axis. Vertical prisms, parallel to the assumed main axis, form rhombic sections, those of the radical exactly cleaving the lateral edges of the 8-hedron. 4-sided prisms, whose planes are parallel to the 2d side axis, corresponding to the 1st horizontal prisms of System III., form rhomboidal sections, and when belonging to the radical 8-hedron, cut its upper and lower edges evenly. 4-sided prisms, parallel to 1st side-axis, form rhombic sections, and are oblique in position. There are three terminal planes of the axes, each of which cuts one axis, and is parallel to the other two; those of the main and 1st side axis cut them obliquely; that of the 2d side axis cuts it at right angles. The main oblique end-plane is a rhomb, and may be called the *base*. In this system it is common to find only a part of the planes of the 8-hedra, and of the prisms in combination,

and hence certain letters are exclusively appropriated to particular planes of a crystal, which is often described by those letters alone; or the planes and prism on the end of a crystal may be distinguished by the terms back and front. Pl. IX., fig. 30, represents the main 8-hedron of Gypsum, *o*, *o'*, with the vertical prism, *g*, and 2d side-plane, *b*; fig. 31 the same with the front oblique prism, *o*. Fig. 32 shows the 1st and 2d side-planes of Felspar, *a* and *b*, with the base, *c*; fig. 33, Felspar, the base, *c*, 2d side-plane, *b*, back oblique end-plane, $2d'$, main vertical prism, *g*, and a vertical prism, $\frac{g}{2}$; fig. 34, the same without $\frac{g}{2}$, but with the back oblique end-plane, d' , and the back oblique end-prism, o' , of the main 8-hedron. Fig. 35, Augite, is a combination of the main 8-hedron, *o*, *o'*, with the back oblique prism, $2o'$, the base, *c*, the main vertical prism, *g*, and the 1st and 2d side-planes, *a*, *b*. A more convenient and clearer mode of representing such complex forms is in horizontal projection, as in fig. 36, which contains the planes enumerated in fig. 35. Glauber's salt resembles fig. 35. Felspar, Augite, Epidote, Copperas, Gypsum, Epsom Salt, especially characterize this system.

V. *Triclinic or Doubly Oblique Rhombic System.* Three axes, unequal, and oblique to each other. This system is characterized by a total want of symmetry, except in some parallel planes, and is therefore diametrically opposite to the regular system; hence the determination of a main axis is altogether arbitrary, and the planes are best noted by letters alone. There are various 8-hedra, vertical and horizontal prisms, and end and side-planes, which may be named as in the preceding system. Axinite often exhibits a very complex combination; one of the simpler forms of this mineral is given in fig. 37, which contains the base, *c*; the left plane of the main 8-hedron, *o*; the oblique end-plane, $2d'$, the right and left planes of the main vertical prism, *g*, *g'*, and the 1st side-plane, *a*. The substances crystallizing agreeably to this system are not numerous; artificial Blue Vitriol illustrates its forms.

VI. *Hexagonal System.* Four axes, three equal, one unequal, and at right angles to the plane of the other three. The three lateral axes cut each other at an angle of 60° . The 4th axis being held vertically, a section at right angles to it is a regular hexagon. The radical form of this system is the *triangular or hexagonal dodecahedron*, fig. 38, which may be viewed as two 6-sided pyramids, joined base to base. These forms are of the 1st order when a face is held towards the observer, of the 2d order when an edge is so held, and several of them occur in the same substance, either acuter or obtuser than the radical or main 12-hedron of that substance. In these and many other relations the hexagonal bears a striking analogy to the quadratic system, II. *Holohedral Forms.* Besides the 12-hedron, the other forms are, 6-sided or *hexagonal prisms*, *g*, fig. 39, *didodecahedron*, or 24-hedra, fig. 40, corresponding 24-hedral prisms, all of which may be of 1st and 2d orders, and the *end-plane* at right angles to the main axis. The 24-hedron,

fig. 40, and its prism differs from a combination of two 12-hedra or prisms, by every alternate angle being equal, but more acute or obtuse than the intermediate angle.

Hemihedral Forms. There are two important hemiforms in this system, the *rhombohedron* and *scaleno-hedron*. The hemi-dodecahedron, $\frac{1}{2}$ 12-hedron, or rhombohedron, is derived from the 12-hedron, by the disappearance of every alternate plane, and when the upper front-plane and its alternates remain, as *r*, fig. 38, the rhombohedron is of the 1st order, as *r*, fig. 42; when the lower, *r*, and its alternates remain, it is of the second order. When derived from the radical 12-hedron of any substance it is the radical rhomb. When the planes of a rhomb of the second order appear, exactly replacing the terminal edges of the radical rhomb, it is the 1st obtuser rhomb; and when the edges of this last are evenly replaced, it is the 2d obtuser rhomb, and is of the 1st order. In like manner, when the lateral solid angles of the radical rhomb are replaced by planes, so that the edges of these planes are parallel on the same face of the radical rhomb, the latter is then evenly cleaving the terminal edges of the new rhomb, which is therefore the first acuter rhomb. The planes of the 1st acuter rhomb appear evenly on the edges of the 2d acuter rhomb. The *scaleno-hedron* is derived from the didodecahedron, fig. 40, by the disappearance of every alternate pair of faces, constituting a 12-planed solid, fig. 46, the planes of which are equal scalene triangles. As of rhombs, there are also acuter and obtuser scalenohedra, and of two orders.

Fig. 38 is the 12-hedron of Quartz, and fig. 39 the same, with the 1st hexagonal prism. Fig. 40 is the didodecahedron of Beryl, and fig. 41 a combination in Beryl of the radical 12-hedron, *r*, with an acuter 12-hedron of the 1st order $2r$, the 1st obtuser 12-hedron, $2d$, of the 12-hedron, $2r$, the didodecahedron, 5, the 1st 6-sided prism, *g*, and the end-plane, *c*. Fig. 42 is the main rhombohedron of Quartz of the 1st order. Fig. 43, Calcareous Spar, is the radical rhombohedron, *r*, with the 1st obtuser, $\frac{2}{3}$; and fig. 44 the radical rhomb, *r*, with the 2d acuter, $4r$. Fig. 45 is the radical rhomb, *r*, of Diopase, with the 2d hexagonal prism. Figs. 46—51 represent Calcareous Spar; fig. 46 is the scalenohedron, $3z$; fig. 47 the scalenohedron $3z$, with the rhomb. of its acuter terminal edges, the 2d acuter rhombohedron, $4r$; fig. 48 the scalenohedron, $3z$, with the rhomb. of its lateral edges, the radical rhomb, *r*; fig. 49 the lateral-edged scalenohedron, $3z$, with the terminal-edged scalenohedron, $2x$, of the radical rhombohedron, and the 1st hexagonal prism; fig. 50 the radical rhomb, *r*, with its side-edged scalenohedra, $3z$, $5z$, the 2d acuter rhomb, $4r$, and the first hexagonal prism; fig. 51 the radical rhomb, *r*, with its side-edged scalenohedron, $3z$, its 1st acuter rhomb, $2r'$, and the side-edged scalenohedron, $\frac{1}{2}$, of the latter. Beryl and Quartz illustrate the holohedral forms, and Calcareous Spar is especially abundant in the hemihedral forms of this system.

COMPOUND OR TWIN CRYSTALS. Two parts of the same crystal are sometimes found

united together, as if the perfect crystal had been halved by a section through it, one half turned round 60° or 180° , and the two parts again united into a perfect whole. In the regular system, the 8-hedron, Pl. VIII., fig. 1, thus cleaved by a central plane, parallel to a face, presents the twinned form, Pl. IX., fig. 52. The regular 12-hedron, Pl. VIII., fig. 2, similarly cleaved and revolved, appears like a hexagonal prism terminated by rhomb. faces. Iron pyrites is sometimes met with, presenting the appearance of one pentagonal 12-hedron, Pl. VIII., fig. 17, within another, the solid angles of one projecting from the planes of the other. In the quadric system, the compounding plane, parallel to an edge of the 8-hedron, is frequently observed, as in fig. 53, Tin Ore, and in Rutile, where the prism makes several successive angles, or geniculations, of a zigzag form. In the right rhombic system compound crystals are more frequently composed of more than two individuals. In the oblique rhombic or monoclinic system, several compounds are observed. Crystals of felspar are found presenting one half of fig. 33, cleaved by a vertical plane passing through *c*, and the common edge of *g*, *g*, joined to the same half of another similar crystal. Thus, if fig. 31 were cleaved by a vertical plane passing through *o* and the centre of *b* (through the main and 2d side-axis), and one half were turned 180° , there would be formed a reentrant angle on one end, and a salient angle on the other, as indeed frequently occurs with Gypsum. In the triclinic system, a similar mode of union present the oblique main terminal plane of the two halves forming a reentrant angle. In the hexagonal system, there are different compounding planes. Fig. 46 is sometimes found twinned by a cleavage through the centre, at right angles to the main axis, as Calc. Spar in fig. 54. Composition also occurs parallel to a plane of a rhomb, radical and derivative, as Calc. Spar in figs. 55, 56, 57. Where parts of several crystals are united by two planes more complex compounds occur, sometimes giving rise to symmetric figures; thus Staurotide, in the right rhombic system, occurs in form of a cross, fig. 58, composed of 4 individuals united on planes parallel to a plane on two terminal edges of the 8-hedron, fig. 59, and on planes parallel to those of the 8-hedron. White Lead in the same system, presents combinations of several individuals parallel to the planes of a vertical prism, as in fig. 60, and when the interstices are wholly filled up, it seems to belong to the hexagonal system, resembling fig. 27. Arragonite, also in the same system, is frequently composed of several individuals, consisting only of a vertical and horizontal prism (or terminal plane), and presenting the appearance of fig. 61, where the edges of two of the individuals not meeting, form a long reentrant angle.

In general, the composition of crystals may be detected by a reentrant angle, or when a surface is level, by the angle formed by striæ along a certain line.

Imperfect crystallizations produce the different kinds of crystalline structure, which consist of individuals aggregated together, and so

disturbed by other forces during their formation, that the regular external form could not be fully developed. This gives rise to the three kinds of structure, columnar, lamellar, and granular. The *columnar* may be *fibrous*, *Asbestos*, *radiated*, *Gypsum*, or *reticulated*, *Asbestos*, the ends of the fibres often presenting regular facets, and sometimes terminating in a smooth curve surface, which is named from its appearance, *globular*, *mammillary*, *Brown Hematite*, or *stalactitic*, *Calcareous Spar*. A body is termed *lamellar* when the crystalline mass is composed of laminæ or leaves, whether plane or curve, as *Gypsum*. The *Granular* structure is sometimes coarse, as *Colophonite*; fine, as *Magnetic Iron*, *Fluor Spar*; and impalpable or compact, as *Chalcedony*, *Flint*. These terms are rather used as convenient in description, as some substances are only found in a crystalline or imperfectly crystallized state.

CUBAN. See **COPPER PYRITES**.

CUBE ORE. *Min. Syn.* Hexahedral Lirocone-malachite, *M.*; *Pharmacosiderite*; *Würfelerz*, *Siderite*. *Descrip.* Cryst. Regular, the cube with $\frac{1}{2}$ 8-hedron, and $\frac{1}{2}$ 24-hedron, and 12-hedron, with cleavage imperfect, parallel to cube. $H. = 2.5$. $G. = 3$. Olive-green, passing into yellowish brown and grass green; lustre adamantine; subtranslucent; rather sectile, with an olive-green brown streak, usually pale.

Chem. Relat. In a closed tube gives off water becoming red; yields arsenical fumes on charcoal, and fuses to a gray, metallic, magnetic slag, which gives an iron reaction with the fluxes. Soluble in chlorohydric acid, and the greater part decomposed by solution of potassa. Form. $3 FeO, As_2O_5 + 3 Fe_2O_3, 2 As_2O_5 + 18 HO$. *Local.* Wheal Goolan, Wheal Unity, Carharrak, Cornwall; St. Leonhard, France; Schneeberg, Schwarzenberg, Saxony.

CUBE SPAR. See **ANHYDRITE**.

CUBEBS, *Oil of.* *Phar. and Chem.* Distilled from the fruit of the *Piper Cubeba*, or Java pepper. An aromatic, colorless, essential oil, of spec. grav. 0.929, which thickens on exposure, without losing its odor, and suffers partial decomposition when distilled without water; boils betw. 482° and $500^\circ F$. Its circular polarizing power is $-40^\circ 1'$, and, according to Soubeiran and Capitaine, $C_{15}H_{12}$, represents its composition, which is in per cent. the same as that of oil of terpentine, the formula however of the atoms of the latter, ($C_{20}H_{16}$), being different. The hydrate of this oil is *steuropten*, which passes over with the last portions of the distilled essence and drops therefrom, after long standing, in rhombic octohedral crystals. These crystals melt at $156^\circ F$, and consist of $C_{16}H_{14}O$. The action of gaseous hydrochloric acid upon the oil generates a crystallized camphor, which is soluble in cold water, and melts at 268° ; its composition according to Soubeiran and Capitaine, is $C_{15}H_{12}Cl$.

Cubebin. A name first given to a partially volatile, greenish yellow mixture of several ingredients, announced by Monheim as a peculiar principle of cubebs. The later re-

searches of Soubeiran and Capitaine have developed the true cubebin, which is a non-volatile body, insoluble in water and ether, but crystallizing in needles (in groups) from its solution in boiling alcohol, by which it is readily taken up. Acetic acid, and the oils generally, also dissolve it. As far as known, it is a neutral body, but its equivalent has not been determined. An analysis of the crystals, however, shows their composition to be $C_{34}H_{17}O_{10}$.

It is obtained by evaporating a strong alcoholic tincture of cubebs (which have been exhausted of their oil by distillation) to one-fourth its bulk, then filtering, and afterwards continuing the evaporation nearly to dryness. By exposure to cold the residuum becomes semi-crystalline, and must then be strained through a cloth to separate the liquid cubebin of Cassola. The solid portion on the filter having been pressed, is then dissolved in four times its weight of alcohol of 0.90, and then boiled. The whole having stood sufficiently long for the deposition of the undissolved resin and impurities, the clear supernatant liquor is decanted and set aside. The crystals which drop are true cubebin, and can be further purified by resolution in boiling concentrated alcohol. Several chemists assert the identity of cubebin with piperin. A distinguishing test is in the fine crimson color imparted to the former by sulphuric acid, and which remains unchanged for many hours.

CUBIZITE. See **ANALCIME**.

CUCUMBER, *Wild. Phar. Syn.* Squirting Cucumber; *Momordica Elaterium*. Grows in the south of Europe, and yields **ELATERIUM**. Annexed are two analyses of the expressed and evaporated juice of the plant.

<i>Dr. Paris's Analysis.</i>	<i>Mr. Hennel's Analysis.</i>
Elatin	} ... 1.2
Bitter matter	
Extractive	 2.6
Fecula	 2.8
Gluten	 0.5
Woody matter	 2.5
Water	 0.4
	10.0
	101

CUCUMIS. See **COLOCYNTH**.

CUDBEAR. *Tech. Syn. Ger. Persio.* Is prepared by the action of air and ammonia upon the expressed decoctions of the *Leonora tartarea*, *Parmelia omphalodes*, and probably other lichens. Found in commerce as a dried paste and a powder, both being used for dyeing; the title Archil, sometimes applied to it, properly belongs to its infusion or liquid violet paste, used for staining wood. The color, though beautiful, is fugitive.

Cudbear is soluble in acidulated water, urine, and alkaline leys: the latter changing it to a blue, and the acids to a red. See **LICHENS** and **LICHENS**.

CUMIN, *Oil of.* *Chem. Phar.* Exists ready formed in the seeds of the *Cuminum Cyminum*, and consists of two oils, a minute quantity of cuminic acid, and some resin. One of the two oils contains oxygen. (*Gerhardt and Cahours*.)

They are termed *Cuminole* and *Cymen*; the former ($C_{20}H_{12}O_2$) a yellowish, sharp tasting and smelling liquid, of spec. grav. 0.969 at 57° , which boils at 437° , and on exposure to air is converted into *cuminic acid*, a similar transformation being produced by liquid chlorine and a mixture of the bichromate of potassa and sulphuric acid. Fused potassa converts it instantaneously into cuminate of potassa, with the disengagement of hydrogen.

The analogy of the derivatives of this oil with those originating from the essence of bitter almonds, allows the supposition of a common radical in the *cuminole*, *cuminic acid*, &c. This radical, styled by Gerhardt and Cahours *Cumyl*, has for its formula, $C_{20}H_{11}O_2 + H$. *Cymen* ($C_{20}H_{24}$), the more volatile portion of the oil of cumin, is a colorless liquid, of the odor of lemons. It has a spec. grav. of 0.861, boils at 347° , and is unalterable in the air and by distillation. Fuming sulphuric acid changes it into sulpho-cymenic acid, and nitric acid transforms it into a crystalline acid, which has not yet been examined. This hydrocarbon (Gerhardt and Cahours) is identical in density and other properties with *camphogen*.

The oil of cumin itself boils at $418^\circ F.$, has a spec. grav. of 0.860, and is represented by formula as $C_{20}H_{12}O_2$.

Cuminic Acid. Formed by the action of potassa upon the oil distilled from the seeds of the *Cuminum Cymibum*. When hydrated its formula is $C_{20}H_{11}O_3 + Aq$. It is in beautiful white tabular prisms when obtained from solution, but in long needles when procured by sublimation; fuses at 197.6° , dissolves readily in ether and alcohol, and is insoluble in water. With the bases it forms salts, some of which are deliquescent, and one or more crystallizable. By distillation with four times its weight of baryta (Gerhardt and Cahours), it is changed into an agreeable smelling, colorless liquid, called *Cumen*, which boils at 291° , and is strongly refractive of light. Its formula is $C_{18}H_{12}$, and as *cuminic acid* yields it by the loss of 2 eq. of carbonic acid, exactly as *benzole* is formed from *benzoic acid*, it is closely analogous to that body, and furthermore is isomeric with *retinylene*, obtained by the distillation of resins, and also with *mesitylene*. *Cumen* is insoluble in water, but dissolves readily in ether, alcohol, and the essential oils, and is unchangeable by potassa. The peculiar crystalline matter, formed by the action of nitric acid, is called *Nitrocumide*, and the acid produced by union with strong sulphuric acid, *sulpho-cumenic*, ($C_{18}H_{12}S_2O_6$), which is analogous to the *sulpho-benzidic*, and forms with the bases well-characterized salts, mostly soluble in ether, alcohol, and water.

CUMMINGTONITE. *Min.* Thin columnar, divergent; ash-gray; silky; translucent, opaque; brittle. $H. = 6 - 6.5$. $G. = 3.2$. Infusible except on thin edges; forms a black glass with borax; fuses with soda, with effervescence to a dark glass. According to Muir's analysis, silica, soda, protoxides of iron, and manganese, with 3 pr. ct. water. The ratio of the oxygen in the silica and bases is 10:3, from which the analysis may be deemed incorrect, or the mineral a mixture.

CUPEL. *Tech.* A flat, porous crucible, on which cupellation is performed.

CUPELLATION. *Tech.* The precious metals, gold and silver, are heated on a cupel to separate impurities from them. On a small scale the operation is performed with great care on small cupels, to determine the quantity of the precious metal. See **ASSAY**. On a large scale silver is obtained from argentiferous lead on the same principle. Such a large cupel, several feet in diameter, is made of bone-ash, or a mixture of it with loam, ashes, &c., in a circular or oval form, hollowed into a basin, in which the lead is melted by a reverberating flame. A current of air from a bellows, driven at an angle upon the surface, oxidizes the lead and other metals, and at the same time drives the fused litharge across to a channel, through which it flows out of the furnace, carrying a mere trace of silver with it. Towards the close of the operation the remainder of the litharge is absorbed by the cupel, together with the other oxides, and nearly pure metallic silver remains.

CUPRANGLESITE. *Min.* Diplogenic Lead-Baryte, *Haid.* Kupferbleivitriol oder spath, Bleilasur, Linarit. *Descrip.* Cryst. Right Rhombic, consisting of horizontal prisms and two terminal planes, to which latter its cleavage is perfect. $H. 2.5 - 3$. $G. 5.3 - 5.5$. Deep azure-blue; vitreous or adamantine; translucent; with pale-blue streak. It gives the reactions of lead, copper, and sulphuric acid, and is composed of $PbO, SO_3 + CuO, HO$. It is only found at Leadhills, Scotland.

CUPRANTIMONY GLANCE. *Min. Syn.* Antimonial Copper. *Ger.* Kupferantimonglanz. It occurs at Wolfsberg, Hartz, in small, aggregated prisms. $H. = 3 - 4$. $G. = 4.47$. Lead-gray to iron-gray; metallic; opaque; with conchoidal fracture and black streak. Fusible, giving off antimonial vapors, and leaving a metallic globule which gives the reaction of copper. Form. Cu_2S, Sb_2S_3 .

CUPROMANGANESE. *Min.* $H. = 1.5$. $G. = 3.15 - 3.25$. Reniform and botryoidal, bluish black, opaque, with resinous lustre. Gives much water, and decrepitates in a closed tube; gives the reaction of manganese, copper, and sometimes of iron and cobalt; is soluble in muriatic acid with evolution of chlorine. Form. $RO, 2 MnO_2 + 2 HO$, in which RO is oxide of copper, protoxides of manganese and cobalt, magnesia, lime, baryta, and potassa.

Local. Kammsdorff, and near Saalfeld; Madison Co., Missouri, U. S., in which latter locality it is due to the decomposition of cupro-cobalt pyrites.

CURARA. The poisonous extract of a plant called *Mavacure*, used by the South American Indians for envenoming the barbs of their arrows. Alcohol extracts an alkaline yellowish mass, of horny aspect, called *Curarin*. (*Boussingault and Raulin*.) It is intensely virulent and bitter. It is very soluble in water and alcohol, but insoluble in ether and alcohol. Heated, it carbonizes. Combined with acids, it forms bitter, uncrystallizable neutral salts.

CURCUMIN. See **TURMERIC**.

CURD. *Tech.* A component of milk, similar

in its chemical characteristics to albumen, and by its susceptibility of fermentation when moist, also resembling vegetable gluten. When on exposure to air or by boiling, the saccharine constituent of milk acquires an acid (lactic) property, its curd portion, owing its liquidity to the presence of potassa, coagulates and separates from the whey in white, tremulous, gelatinous masses. The curd formed by *rennet* is called *Casein*, and mixed with butter is the basis of common cheese. The *coagulum*, eliminated by acetic acid from the liquid, after *rennet* ceases to have action, is termed *Zeiger*, or *Serai*. See MILK.

CURRY. *Tech.* A renowned sauce, much used in many articles of Indian cookery, and derives its name from the curry-powder (*Tunmeric*) with which it is colored and partially seasoned. Of the many modifications of this condiment, the following is the most generally approved.

King of Oude's Sauce. To a sufficient quantity of very finely minced meat add $\frac{1}{2}$ lb. fresh butter, 2 large onions, 1 gill of good veal-gravy, a table spoonful of curry-powder, and simmer the whole in a covered pan for two hours. When ready to be served up, squeeze in as much lemon-juice as is necessary to give it an acid flavor. (*Murray*.) To suit some tastes a garlic is occasionally added.

CUSPARIN. See *ANGOSTURA*.

CYAMELIDE. See *CYANOGEN* and *Oxygen*.

CYANITE. See *KYANITE*.

CYANOGEN. *Chem.* *Kuzavce, blue, cyanogen.* *I generate*, from its earliest known compound, Prussian blue. Discovered in 1815, by Gay-Lussac, and since then studied by many chemists.

	H = 1	O = 100	
C ₂	12.02	150.24	45.90
N.....	14.18	177.04	54.10
	26.20	327.28	100.00

Form. C₂N. Sym. Cy.

Formation. It is formed when one or both of its elements are in their incipient state, with the presence of another body with which the cyanogen may unite. Thus, when ammoniacal gas is passed over charcoal at a white heat, cyanide of ammonium and free hydrogen result; $2\text{NH}_3 + \text{C}_2 = \text{NH}_4, \text{C}_2\text{N} + \text{H}_2$. If carbonate of potassa be present, cyanide of potassium, water, hydrogen, and carbonic acid result; $\text{NH}_3 + \text{C}_2 + \text{KO}, \text{CO}_2 = \text{K.C}_2\text{N} + \text{HO} + \text{H}_2 + \text{CO}_2$. When mingled, ammonia-gas and carbonic oxide; or when the gaseous oxides of nitrogen, with carburetted hydrogen or vapor of alcohol, are heated in presence of platinum sponge, cyanide of ammonium is formed. It is also formed by the metamorphosis of various organic bodies, as by heating formiate of ammonia, by the action of emulsin on amygdalin with water, &c.

Prep. By heating in a small retort neutral, dry cyanide of mercury, below redness, it becomes black, semi-fuses, and evolves cyanogen and mercury, the former of which is caught over mercury, or may be burned at the

exit tube, finely drawn out to exhibit its flame. Moisture, or too high a temperature, render the gas impure. Paracyanogen remains.

Prop. A colorless gas, with a strong, peculiar odor, irritating the eyes and nose powerfully, burning with purplish flame: spec. grav. = 1.8064; compressible by 3 or 4 atmospheres, or by cold, into a thin, colorless liquid, of spec. grav. 0.9 (by Faraday's apparatus). Water dissolves $4\frac{1}{2}$ vols. cyanogen, receiving its characteristic odor and a sharp taste. The solution decomposes, depositing a brown substance with the composition, $\text{C}_2\text{N} + \text{HO}$, and then containing prussic and carbonic acids, ammonia, urea, and oxalate of ammonia. The brown substance, at a red heat, forms paracyanogen. A trace of acid in the water protects the cyanogen. Alcohol dissolves 23, ether 5 vols. cyanogen, and the solutions decompose similarly to that of water. Cyanogen supports a very high temperature without decomposition, but by passing over white-hot iron, it is resolved into carbon and nitrogen, and heated with oxygen or oxide of copper into 2 vols. carbonic acid and 1 vol. nitrogen.

Cyanogen combines directly with potassium and sodium; with the fixed alkalies it forms a cyanide and cyanate; other cyanides are formed by double decomposition. In nearly all its relations it exhibits a great degree of fixedness, and the closest analogy with the halogens, with a peculiar difference due to its compound nature, and other peculiarities, such as the formation of Sulphocyanides, &c.

Cyanogen may be determined in its compounds by ultimate organic ANALYSIS, or by precipitating it with nitrate of silver, weighing, igniting, and again weighing, to ascertain the loss of cyanogen; if chlorine be present at the same time, the mixed chloride and cyanide of silver is weighed, converted into chloride by muriatic acid, and the cyanogen calculated by the difference.

Paracyanogen remains as a coal-like body when cyanogen is prepared from cyanide of mercury or silver; or it is obtained by igniting the brown precipitate from a saturated solution of cyanogen in alcohol, or from aqueous prussic acid. It is brown, amorphous, infusible. Probable formula NC_2 ; isomeric, with cyanogen. (*Johnston*.) The decomposition of cyanide of silver is attended by the evolution of light and heat, when one half of the cyanogen has passed off and paracyanogen remains, but the gas appears to be another isomeric form of cyanogen, *metacyanogen*. These bodies have not been thoroughly investigated.

Cyanohydric Acid. *Chem. Phar.* Syn. Hydrocyanic, Prussic acid. *Ger.* Blausäure, Cyanwasserstoffsäure. Form. $\text{C}_2\text{NH} = \text{HCy}$. Eq. = 27.2 or 339.78.

Prep. It is obtained like the halogen hydracids, by the action of acids on cyanides.

To prepare the anhydrous acid: 1. Pour concentrated muriatic acid over finely powdered cyanide of mercury in a tubulated retort, the neck of which passes into a tube several feet long, the first third containing marble, the remaining $\frac{2}{3}$ fused chloride of calcium. By gently warming the retort, the acid passes

over and condenses first in the tube, where the marble and chloride of calcium retain muriatic acid and water, and from which the cyanohydric is driven by warmth into a receiver cooled by ice. By theory, $\text{HgCy} + \text{HCl} = \text{HgCl} + \text{HCy}$, but a portion of formiate of ammonia is also produced. (*Gay-Lussac*.) 2. Pass dry, sulphuretted hydrogen over the cyanide of mercury in a long, glass tube, containing white lead at the end, to catch sulphuretted hydrogen; $\text{HgCy} + \text{HS} = \text{HgS} + \text{HCy}$. (*Vauquelin*.) 3. Distil 15 pts. yellow prussiate of potash with 9 pts. sulphuric acid, and 9 pts. water, and into the cooled receiving flask throw chloride of calcium, which forms a heavy solution from above which the liquid cyanohydric acid may be decanted; by repeated standing with the chloride it may be obtained fully anhydrous. (*Trautwein*.) 4. Dissolve 2 pts. of the crude mass of cyanide of potassium (by *Liebig's* process) in 5 to 6 pts. water, introduce it into a tubulated retort, and upon it one part oil of vitriol, previously diluted with one part water and cooled. The acid is added in small quantities at a time to avoid too much heat. From the beak of the retort a small tube enters a $\frac{1}{2}$ to $\frac{3}{4}$ inch tube, 3 ft. long, which is bent into a syphon-form, filled with chloride of calcium, and placed inverted in a cylinder filled with cold water; a tube passes from the other end of the syphon into a flask surrounded with ice and salt (or ice alone). When all the acid has been poured in, and the liquid ceases to boil, the water in the cylinder is drawn off by a syphon, and replaced by water at 86° to 95° , which is heat sufficient to drive over the prussic acid from the chloride syphon-tube into the condensing flask, and to insure more perfect condensation, the small tube entering the flask may pass through a *Liebig's* condenser. The retort may then be heated to obtain more acid. (*Liebig*.) The dangerous nature of this acid demands great care, especially the use of ice, or ice and salt, in its preparation.

Prop. A colorless, very thin flowing liquid, of peculiar taste, and strong odor, numbing the nasal organs; spec. grav. = 0.6969 at 64° ; congealing into a white, fibrous mass at $+5^{\circ}$, (not at -56° , *Schulz*); boiling at 79° ; spec. grav. of vapor = 0.9476; very combustible, with a luminous, reddish flame; miscible in all proportions with water, alcohol, and ether, imparting a bitter-almond taste. It is one of the most deadly poisons, the more so from its volatility. It is decomposable in a manner similar to cyanogen by iron, oxygen, or oxide of copper; and even spontaneously in close vessels, forming a brownish black substance and ammonia, but traces of other acids prevent change. Strong acids change it into ammonia and formic acid, chlorine into muriatic acid and chloride of cyanogen. Potassium, heated in its vapor, forms cyanide with evolution of hydrogen; baryta or lime have the same result, but form both cyanide and cyanate; many metallic oxides form cyanides and water.

From the above it would evidently be easy to prepare liquid, aqueous prussic acid, but

for medicinal use, its highly poisonous character demands great care in preparing it of an exact strength. The per centage of anhydrous acid in the aqueous acid varies greatly in different Pharmacopœias, being 1.6 pr. ct. in the U. S. Phar., and 12 pr. ct. in the Parisian.

1. Put 4 pts. ferrocyanide of potassium in a glass flask, add 16 pts. hot water to dissolve it, and, when cooled, add 2 pts. oil of vitriol, previously mixed with 2 pts. water, connect with a tall receiver, containing 20 pts. water, and distil until a mark on the receiver shows 38 pts. The liquid contains $2\frac{1}{2}$ pr. ct. dry acid. (*Geiger*.) The London and U. S. Pharm direct 3ij ferrocyanide, and 3jss sulphuric acid. 2. One part ferrocyanide is distilled with 2 pts. pure phosphoric acid (spec. grav. of the solution = 1.135) and 3 pts. alcohol (spec. grav. = 0.81), until a somewhat moist mass remains, receiving the acid in 1 pt. alcohol in a receiver. 3. Dissolve 22 grs. cyanide of potassium in 6 flz. water, add 50 grs. cryst. tartaric acid, dissolved in 3 flz. rectified spirit, and after standing some time decant. $\text{KCy} + 2\text{T} + \text{HO} = \text{KO}, 2\text{T} + \text{HCy}$. (*Laming*.) The small amount of cream of tartar remaining in the acid, is perhaps not objectionable for medical purposes, but there is a difficulty in the uncertain purity of the cyanide. 4. Cyanide of silver is exactly decomposed by chlorohydric acid (*Everitt*). $\text{AgCy} + \text{HCl} = \text{AgCl} + \text{HCy}$. The U. S. Pharm. employs 51 grs. cyanide, and 41 grs. muriatic acid. If the strength of the latter acid could be exactly known, this process is a good one. Cyanide of mercury may be substituted for that of silver. 5. Prepare the dry acid as above given (process 4) in a cooled and graduated receiver, and add water q. s. cooled to 32° . To make an acid containing $3\frac{1}{2}$ pr. ct. dry acid, to 5 measures of the dry acid obtained, add $96\frac{1}{2}$ measures water. *Liebig*.

Prop. Like the dry acid dissolved in water, it is very subject to decomposition, which may be prevented by a slight acidulation with another acid. The pure acid should leave no residue on evaporation, sulphuric acid and yellow prussiate are detected respectively by a salt of baryta and a persalt of iron, muriatic acid by nitrate of silver, and observing if the precipitate wholly dissolve in hot, concentrated nitric acid. To determine the amount of acid in a solution, precipitate a given weight of it entirely with nitrate of silver, collect on a weighed filter, dry it at 300° , and weigh. Every 5 grs. (exactly 4.88) cyanide correspond to 1 gr. dry acid. Or the precipitate, dried on an unweighed filter, is burned in a porcelain crucible and the silver weighed, every 4 grs. (3.922) of which are equivalent to 1 gr. of anhydrous acid. See also *Hyduret of BENZYL*.

Cyanides. Those of potassium and sodium may be formed directly, but they are all made indirectly, and from ferrocyanide of potassium, which is prepared on a large scale for use in the arts. The cyanides are all solids, often presenting a close analogy with the chlorides, and like the latter, forming an extensive series of double salts. The alkaline cyanides are

soluble in water, have an alkaline reaction, and with excess of alkali or prussic acid readily decompose; boiled with alkali, they form ammonia and formiates. The cyanides of the noble metals are decomposed into cyanogen and metal or a lower cyanide. Cyanides have a remarkable tendency to form double salts, and some of these again unite, forming quadruple salts or twinned double salts. The ferrocyanide of potassium being the basis of nearly all the compounds of cyanogen, the following view of its manufacture is presented, as explained by Liebig.

MANUFACTURE OF YELLOW PRUSSATE OF POTASH.

The materials employed are animal matters, containing nitrogen, blood, hoofs, horns, hides, cracklings, woollen rags, hair, leather, and all nitrogenous animal offals, which are calcined in their dried state with potash, or previously charred in retorts, and then fused with potash. The latter process is desirable where ammoniacal products are to be obtained, and was indeed the process originally pursued until within a few years. In this case the offals were distilled in iron retorts to catch the ammoniacal water and tarry matters, and the charcoal remaining then thrown into the fused potash. It was found that the less the offals were distilled, the greater was the proportion of prussiate obtained, and hence the substitution, latterly, of the dried but uncharred offals for the animal charcoal. Ammoniacal products may be obtained from other sources.

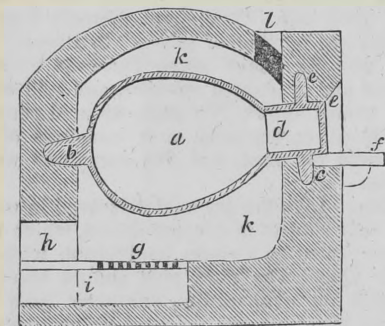


Fig. 39.

The pear-shaped iron vessel for fusing the offals with potash, is represented in fig. 39, on a scale of $\frac{1}{4}$ inch to the foot, in which *a* is the pot of cast iron, 2 inches or more thick on the bottom, to withstand the erosive action of the mass, built in brickwork, and sustained at the back by a thick tongue, *b*, which enters the masonry, and in front by the arms, *c*, *d*; the narrow opening through which the charge is introduced and worked, and may be closed by an iron plate, *e*; *f*, an iron shelf to prevent loss in drawing out the charge; *g*, the grate; *h*, the fire-door, and *i*, the ash-pit, placed at the back, as in the figure, or at the side; *k, k*, a space of a few inches left around the pot to allow the flame to encircle it more closely; *l*, the flue, whence the gaseous products of the fire pass into the chimney.

When the potash is brought to fusion in the pot, the animal matter is thrown in gradually

during several hours, the mass being frequently stirred by an iron paddle, until ammoniacal vapor is perceived, when the opening, *d*, is closed by the plate, *e*, and a brisk fire given, during which it is opened and the mass stirred at intervals. When the flame ceases, or carbonaceous matter has disappeared, the thick mass is drawn out, quickly cooled, apart from the air if possible, dissolved by warm water, filtered, and the solution evaporated for crystallization. To meet the excess of cyanide of potassium, copperas may be added. A second solution and crystallization yield a good commercial prussiate.

The proportion of materials employed varies in different establishments. The following table shows the relative proportion of different offals and potash sometimes employed.

For 100 pts.	Potash.	Iron.	Pr. et. yield.
Dry blood.....	28—30	2—4	8—9
Horn	33—35	2—4	9—10
Leather.....	45—48	2—4	5—6

According to this statement, horn yields the largest per centage of prussiate, leather yields a comparatively small amount, and yet requires a larger proportion of potash. Cracklings, or the membranous residue of rough tallow, suet, and lard, when rendered, being highly nitrogenous are the most economical material. In the West the supply is unlimited, and they mostly retain so much of fat that it pays the expense of its separation, together with the original cost. For the minutiae of the process of extracting, see *Morfil's Applied Chemistry*, p. 332.

Theory of the Process. The crystallized salt is a hydrate, containing just so much water that its oxygen exactly forms protoxide of iron and potassa, and its hydrogen cyanohydric or prussic acid, $2 \text{KCy} + \text{FeCy} + 3 \text{HO} = 2(\text{KO}, \text{CyH}) + \text{FeO}, \text{CyH}$. By a moderate heat the water is expelled, and by igniting the dry salt in close vessels, cyanide of potassium, and carburet of iron remain, while nitrogen escapes. If it be mixed with potash and ignited, cyanide of potassium and protoxide of iron remain, and carbonic acid escapes; and if charcoal were used with the potash, metallic iron remains with the fused mass. The double cyanide cannot, therefore, exist ready formed in an ignited mixture of potash and charcoal. To prove this, if the finely powdered mass from the pot be lixiviated with dilute alcohol instead of with water, the clear liquid contains only cyanide of potassium, and no trace of the double cyanide, which cannot even now be extracted by hot water, but by digesting the alcoholic solution with the lixiviated residue at a gentle warmth, the solution becomes yellow. It is then evident that the yellow prussiate is only formed while digesting the fused mass with water, and the manner in which the double cyanide is formed may be explained as follows:

Cyanide of potassium has a twofold origin, when nitrogenous animal matters are ignited with potash, by the presence of potash, and by the decomposition of ammonia with charcoal. 1. When potash (carbonate of potassa) is highly heated with charcoal, both acid and

base are robbed of oxygen, and potassium and carbonic oxide are produced. Cyanogen contains 1 eq. nitrogen to 2 eq. carbon, and animal matters 1 to 6; hence, when potash is heated with blood charcoal, containing nitrogen, the excess of carbon tends to reduce the potassa to potassium, which then induces the union of 1 eq. nitrogen to 2 eq. carbon to form cyanogen, with which it combines to cyanide of potassium. 2. The dry distillation of blood, &c., gives rise largely to ammoniacal products. By passing ammonia-gas over ignited wood-charcoal, it is converted into cyanohydric or prussic acid and hydrogen; thus $\text{NH}_3 + \text{C}_2 = \text{C}_2\text{N} + \text{H} + \text{H}_2$. The prussic acid thus produced, when animal matters are thrown into fused potash, then unites with the ignited potassa to hydrocyanate of potassa (cyanide of potassium), and the presence of the base no doubt induced the more ready resolution of ammonia into cyanogen.

When uncharred animal matter is thrown into the fused potash, the first stage of the process is the evolution of ammoniacal vapor, which is reduced by the excess of carbon and forms one portion of cyanide of potassium. The second stage is the reduction of potassa, by the excess of carbon, and the formation of another portion of cyanide. This was the only source of cyanide in the older process, where the blood, &c., was previously charred. Hence the gain in the more modern process of a larger amount of cyanide, where uncharred animal matter is used.

From what has been said, cyanide of potassium, and not the double salt with iron, is formed by the fusion in the manufacturing process, and the way in which iron enters into combination will appear from the behaviour of cyanide of potassium to iron. When iron is digested in a retort, with a pretty strong solution of this salt, it is dissolved with the evolution of hydrogen, the liquid becoming yellow from the formation of yellow prussiate and being very alkaline. Thus of 3 eq. of the cyanide, 1 eq. is decomposed, its cyanogen uniting with iron, and its potassium with oxygen from water, whose hydrogen is set free; caustic potassa will therefore be in solution. Thus $3\text{KCy} + \text{Fe} + \text{HO} = 2\text{KCy}, \text{FeCy} + \text{KO} + \text{H}$. A similar solution, exposed to the air, absorbs oxygen from it, producing the same result, without evolving hydrogen. When solutions of protosulphate of iron and cyanide of potassium are brought together, the reddish yellow precipitate dissolves by digestion to a yellow solution containing yellow prussiate and sulphate of potassa; 1 eq. potassium and 1 eq. of iron mutually replacing each other. Thus, $3\text{KCy} + \text{FeO}, \text{SO}_3 = 2\text{KCy}, \text{FeCy} + \text{KO}, \text{SO}_3$. But protosulphuret of iron dissolves more rapidly in the cyanide than either iron or its protoxide; $3\text{KCy} + \text{FeS} = 2\text{KCy}, \text{FeCy} + \text{KS}$, so that the yellow prussiate and sulphuret of potassium are formed. It is to be observed that the presence of potassa or its carbonate does not in the least impede these changes.

All these operations take place in the manufacturing process. By the fusion cyanide of potassium is formed; but the potash of com-

merce contains 12 to 16 pr. ct. sulphate of potassa, which is reduced to potassa and bisulphuret of potassium. This bisulphuret takes up metallic iron, forming a fusible, mixed sulphuret, which is disseminated through the whole mass. Hence the rapid erosion of the iron vessels, notwithstanding the addition of metallic iron to the mass.

When the fused and cooled mass is digested with water, the sulphuret of iron is decomposed, (see formula above,) and yellow prussiate formed, but if the quantity of sulphuret were insufficient to form this salt with all the cyanide of potassium, the latter is decomposed by the free alkali, forming ammonia and formic acid; $\text{KC}_2\text{N} + 4\text{HO} = \text{KO} + \text{C}_2\text{HO}_3 + \text{NH}_3$. Hence a frequent and considerable loss in the manufacture. To obviate this, protosulphate of iron is added during the digestion, and is converted by the sulphuret of potassium present into sulphuret of iron. It is added in solution until a black precipitate is formed, which no longer dissolves in the boiling liquid.

There is another source of loss arising from the decomposition of bisulphuret with cyanide of potassium, resulting in the formation of sulphocyanide of potassium. But the formation of this salt may be prevented by the addition of sufficient iron to the fusing mass, whereby the sulphocyanide is resolved into cyanide of potassium and sulphuret of iron.

Another cause of loss arises from the access of air during the fusion, whereby cyanate of potassa is formed by the absorption of oxygen. The same acid is also formed by the reaction of sulphate of potassa on cyanide of potassium.

In consequence of the views above given, some manufacturers free their potash from sulphate by crystallization, and employ sulphuret of iron, metallic iron, smithy slack during the digestion of the fused mass with water. In this case the iron kettles should scarcely be eroded. By due attention to the above views, coupled with a few more experiments, it is evident that the manufacture may be much improved.

CYANIDES.

1. *Cyanide of Potassium.* Form. KCy . Prep. 1. By adding hydrocyanic acid in excess to a recently prepared concentrated solution of caustic potassa, evaporating the solution in a retort at a boiling heat till crystallization commences, when it must be poured into a porcelain capsule, and fused at a low red heat. 2. By heating the ferrocyanide of potassium, carefully dried and reduced to a fine powder, in an iron vessel or well-closed crucible to a strong red heat, exposure to the air being carefully avoided till quite cold; the semi-fused and porous mass reduced to a fine powder, is placed in a funnel, moistened with a little alcohol, and then washed with cold water. The first concentrated colorless solution which passes off, is rapidly brought to dryness and fused in a porcelain capsule. The pounded fused mass may also be boiled in dilute alcohol when the cyanide is deposited pure on cooling. Alcohol of 60 pr. ct. dissolves at the boiling temperature a considerable quantity of

the cyanide, almost the whole of which is again deposited as the solution cools.

Prop. Colorless; crystallizes in transparent cubes, or other forms of the regular system, without odor, but of a sharp biting alkaline and bitter-almond taste; fuses readily to a clear, transparent liquid, and will bear a white heat without decomposition in close vessels, but if exposed to oxygen, is converted into cyanate of potassa. On exposure the crystals become opaque, deliquesce in a moist atmosphere, are very soluble in water, the solution is decomposed even by the carbonic acid of the air, and smells of prussic acid; even in close vessels it decomposes after some time.

It is converted, in solution in water, into hydrocyanate of potassa; if the solution be evaporated with an excess of potassa, the whole of the nitrogen is evolved as ammonia, and formiate of potassa remains. Effervescence on the addition of an acid proves the presence of carbonic acid; a yellow color, that of iron; and a blackening, when heated, the admixture of salts of formic acid. It is a powerful mean of reducing metallic compounds to the state of metal, and is hence an invaluable reagent for the blowpipe.

2. *Cyanide of Sodium*, NaCy , prepared in the same manner, has the same properties as the cyanide of potassium.

3. *Cyanohydrate of Ammonia*, or *Cyanide of Ammonium*. Prepared by distilling dry ammoniacal salts with metallic cyanides, or by bringing anhydrous cyanohydric acid into contact with ammoniacal gas, when the compound is produced in the form of bright crystalline plates. It is almost as volatile as prussic acid itself; decomposes very rapidly in water, is poisonous, and has a strong, peculiar odor. Form. NH_4Cy .

Cyanogen and Ammonia. If cyanogen gas be conducted into liquid ammonia, a large quantity of a brown substance, which contains ammonia in chemical combination, is deposited; the soluble products are like those when cyanogen is dissolved in water. According to Johnston, its composition may be represented by the form. $\text{C}_6\text{N}_4\text{H}_6\text{O}_4$, or $\text{C}_6\text{N}_3\text{O} + \text{NH}_3 + \text{H}_2\text{O}_3$, consequently as a hydrated ammoniacal compound of an acid, which contains the same quantity of cyanogen as the cyanuric acid, and may therefore be considered as the protoxide of the radical of the latter acid. By heating this brown precipitate to redness, paracyanogen, water, and carbonate of ammonia are obtained.

4. *Cyanide of Zinc*. Form. ZnCy . The acid solution of acetate of zinc is treated with cyanohydric acid as long as a precipitate is formed, which is washed and dried. A brilliant white, tasteless powder, insoluble in water and alcohol, but perfectly soluble in ammonia, as also in dilute chlorohydric acid with the evolution of cyanohydric acid.

5. *Cyanide of Iron*. Form. FeCy . This compound, remarkable from its tendency to form a very peculiar class of double compounds by uniting with other cyanides, appears incapable of existing in a free state as the corresponding

protoxide. On adding a proto-salt of iron to a solution of cyanide of potassium, a yellowish red precipitate is formed, and redissolved by an excess of the cyanide into a yellow liquid, the ferrocyanide of potassium. On heating dry ferrocyanide of ammonium, cyanide of ammonium is evolved, and a gray, insoluble powder remains, which has been considered as this compound. It is also produced, according to Robiquet, by pouring a saturated solution of sulphohydric acid over recently prepared Prussian blue contained in a well-stoppered vessel; the blue becomes white, and the solution contains cyanohydric acid. The properties of these preparations differ too widely to allow of their being considered as identical.

6. *Sesquicyanide of Iron*. Fe_2Cy_3 . Unknown in a pure state. On mixing a solution of ferridcyanide of potassium to the silico-fluoride of iron, the silico-fluoride of potassium is separated, and a deep, brown liquid remains, which has a strong astringent taste, becomes blue on evaporation, and leaves a residue of Prussian blue. It forms a numerous class of double cyanides.

7. *Ferroferride Cyanide*. $\text{Fe}_3\text{Cy}_4 + 4\text{HO} = \text{FeCy} + \text{Fe}_2\text{Cy}_3 + 4\text{HO}$. Obtained by boiling the green powder, which falls on heating or exposing to the air a solution of ferrocyanide of potassium charged with an excess of chlorine, with 8 to 10 times its weight of concentrated hydrochloric acid, until the filtered solution ceases to be rendered turbid by water. The green residue, when well washed, should be dried in vacuo; it is but slightly acted upon by concentrated hydrochloric acid, or by chlorine, but it is readily decomposed by hydrate of potassa into peroxide of iron and ferrocyanide and ferridcyanide of potassium. *Pelouze*.

8. *Cyanide of Cobalt*. CoCy . Formed by mixing a solution of the acetate of cobalt with hydrocyanic acid, is a brownish white precipitate.

9. *Cyanide of Nickel*. Formed by precipitating acetate of nickel with prussic acid, is an apple-green hydrate, which becomes light-brown anhydrous cyanide, NiCy , by heating. Its double salts see below.

10. *Cyan. of Lead*, is white, insoluble, and appears to be a basic cyanide like those of the alkalies.

11. *Subcyan. of Copper*, formed by the hydrated red oxide and prussic acid, is white, and soluble in ammonia. *Cyanide of Copper*, formed from hydrate or carbonate of copper, is a yellow powder, insoluble in water, soluble in muriatic acid, precipitable with water. It forms double salts.

12. *Cyanide of Mercury*. Form. HgCy . *Prep.* 1. An aqueous solution of prussic acid is treated with finely powdered red oxide of mercury until all odor of the former disappears; the liquid yields on evaporation pure crystals of the cyanide. The acid prepared by Geiger's method is most convenient, and should be introduced into a well-stoppered bottle, the combination with the oxide of mercury being promoted by frequent agitation. It must al-

ways be remembered, that the compound can only be produced when water is present in sufficient quantity to dissolve the whole of the cyanide; water must therefore be added, should it be observed that the liquid smells of prussic acid, while any portion of the oxide of mercury remains undissolved. 2. By adding to a solution of 2 pts. of ferrocyanide of potassium in 15 pts. of boiling water, 3 pts. of dry bisulphate of mercury; boil the mixture for $\frac{1}{2}$ hour, and separate the clear liquid while boiling hot from the precipitate by filtration; as the solution cools, the cyanide crystallizes. The mother-liquor yields a second crop of crystals by evaporation; or it may be evaporated to dryness, and the cyanide obtained from the residue by boiling alcohol. The first crystals from the aqueous solution are purified by a second crystallization. The formation of the cyanide in this process is owing to the mutual decomposition between the 2 eq. of cyanide of potassium of the ferrocyanide and 2 eq. of sulphate of mercury into cyanide of mercury and sulphate of potassa, while the cyanide of iron is precipitated.

Prop. Crystallizes in colorless, transparent, regular 4- or 6-sided prisms; they are anhydrous, permanent in the air, of a very disagreeable metallic taste, and very poisonous, soluble in 8 pts. water at 60°, but more so in boiling water, and in alcohol.

Oxide of mercury decomposes all soluble metallic cyanides with the formation of an oxide and double cyanides of mercury and other metals. If the cyanide be boiled with an excess of oxide of mercury, the latter is dissolved in large quantity, and the solution, on evaporation, deposits a compound in fine acicular crystals, $\text{HCy}, 3 \text{HO}$; they are more soluble in cold water than the cyanide, and have an alkaline reaction. The formation of this compound, during the preparation of the cyanide, must be carefully avoided, by the careful addition of cyanohydric acid until its odor is perceptible.

A subcyanide corresponding to the suboxide of mercury is unknown. When an attempt is made to obtain it by adding a subsalt of mercury to prussic acid, metallic mercury is instantly separated, and cyanide formed.

13. *Cyanide of Silver.* AgCy . Falls, on mixing a soluble salt of silver with cyanohydric acid, in the form of a brilliant white curdy precipitate; is decomposed by all hydracids, but with great difficulty by other mineral acids, except boiling nitric; suffers no change by the caustic fixed alkalies, is readily dissolved by ammonia. It is readily soluble in a concentrated solution of the nitrate of silver, forming with it a crystalline compound, decomposed by water. It forms double cyanides with other metallic cyanides.

14. *Cyanide of Palladium.* PdCy . The affinity of palladium for cyanogen surpasses that of all other metals; they combine, whenever cyanohydric acid or any soluble cyanide is added to a salt of protoxide of palladium, in the form of a light brownish yellow precipitate with a greenish tint if copper be present; forms double salts with ammonia, cyanide of potassium, and nitrate of palladium.

15. *Cyanide of Gold.* Form. AuCy . Obtained by treating aurocyanide of potassium (see below) with muriatic acid, and evaporating in a water-bath to dryness, and dissolving out cyanide of potassium with water, forms a yellow crystalline powder, insoluble in water, alcohol, and ether.

16. *Cyanide of Gold.* Form. AuCy_3 . A solution of gold in aqua regia, carefully deprived of all free acid by evaporation, is treated by a recently prepared solution of cyanide of potassium with an excess of hydrocyanic acid, leaving a small quantity of the chloride of gold in solution. The yellowish white gold cyanide is collected, washed, and dried. An excess of cyanide of potassium dissolves it with a yellowish red color, but it is re-precipitated by addition of an acid. It is prepared by adding to 16 pts. gold dissolved in aqua regia, a boiling solution of 24 pts. of cyanide of mercury, evaporating to dryness, and washing with water.

DOUBLE CYANIDES.

All insoluble metallic cyanides (of heavy metals) combine with the soluble (of alkaline metals) to peculiar, generally crystallizable, double compounds, which are very similar in their general properties to the combinations of the soluble and insoluble metallic sulphurets. Thus the cyanides of gold, palladium, silver, nickel, zinc, copper, &c., are readily dissolved by the cyanide of potassium or sodium, forming either yellow or colorless solutions, which are not changed or decomposed by the caustic or carbonated alkalies, or by metallic chlorides; acids precipitate insoluble cyanide, owing to the decomposition of the soluble cyanide. On mixing a double cyanide of potassium or sodium with a salt of a proper metal, a new double compound is generally formed, in which the alkaline metal is replaced by its equivalent of the heavy metal. The double cyanide of silver and potassium, $\text{KCy} + \text{AgCy}$, forms, with acetate of lead, PbO, A , the double cyanide of silver and lead, $\text{PbCy} + \text{AgCy}$, and acetate of potassa. The soluble metallic cyanides often form double compounds with the insoluble metallic chlorides, bromides, and iodides.

The double compounds of both cyanides of iron and the cyanide of cobalt with other cyanides, and with cyanohydric acid, are peculiar; the latter are soluble in water, crystallizable, of a distinct acid taste, redden litmus, permanently decompose carbonates with effervescence, and perfectly neutralize the alkalies; properties not possessed by the free cyanohydric acid. Neither the iron nor the cobalt in these compounds can be detected by the alkalies, by the soluble metallic sulphurets, or, in short, by any of the ordinary reagents.

Theoretic Composition. Several views have been proposed for representing the composition of these compounds. According to Berzelius they are double salts, similar to other double salts, in which 1 eq. of ferrocyanide is united with 2 eq. of another cyanide, and 1 eq. of ferrid- or cobaltidecyanide, with 3 eq. of another cyanide.

Berzelius.	Liebig.
Cyanide of iron = FeCy	FeCy
Ferrocyanhydric acid..... = FeCy, 2 HCy	Cfy + H ₂
Ferrocyanide of potassium..... = FeCy, 2 KCy	Cfy + K ₂
Ferrocyanide of pot. and calc... = FeCy, 2 KCy + FeCy, 2 CaCy	Cfy + { $\begin{matrix} K \\ Ca \end{matrix} \}$
Ferridcyanhydric acid..... = Fe ₂ Cy ₃ , 3 HCy	Cfdy + H ₃
Ferridcyanide of potassium.... = Fe ₂ Cy ₃ , 3 KCy	Cfdy + K ₃
Prussian Blue..... = 2 Fe ₂ Cy ₃ , 3 FeCy	{ Cfdy, Fe ₃ + Cfy, Fe or 3 Cfy + 2 Fe ₂ + Fe ₂ O ₃
Basic Prussian Blue..... = 2 Fe ₂ Cy ₃ , 3 FeCy + Fe ₂ O ₃	3 Cfy + 2 Fe ₂ + Fe ₂ O ₃
Cobaltidcyanhydric acid..... = Co ₂ Cy ₃ , 3 HCy	Cky + H ₃
Cobaltidcyanide of potassium.. = Co ₂ Cy ₃ , 3 KCy	Cky + K ₃

Liebig assumes the radicals *Ferrocyanogen* = FeCy₃, symbolized by Cfy, and *Ferridcyanogen* = Fe₂Cy₃, written Cfdy. These views are presented in the above table. Graham proposed a radical Prussine = Cy₃, whence the ferrocyanhydric or prussic acid would be Pr + H₃, or the acid prussohydrate of iron. The formulæ of Liebig and Graham have the advantage of simplicity, but we shall at present follow the views of Berzelius.

Besides the double salts of the cyanides of iron there are other classes of double salts, such as those of nickel, copper, palladium, &c., which are more simply viewed as double salts, or as simple salts, in which one cyanide acts the part of an acid to another cyanide as a base. On the theory of Liebig there should be as many compound radicals as there are classes of these compounds. See Remarks of Dr. Hare on the Compound Radical Theory.

1. *Ferrocyanhydric Acid*. Syn. Ferruretted Chyazic acid. *Ger.* Eisenhaltige Blausäure. Form. 2 HCy, FeCy. Discovered by Porrett. *Prep.* 1. Decompose recently precipitated ferrocyanide of lead or copper by sulphuretted hydrogen, filter, to separate the metallic sulphuret, and evaporate over sulphuric acid in vacuo. (*Berzelius*.) 2. Mix pure Prussian blue with ten times its volume of concentrated hydrochloric acid, and as soon as the blue color has disappeared, wash the yellowish or brown insoluble residue with fresh portions of the concentrated acid; spread the moist mass upon a clean tile, placed under a bell-jar with quick lime, dissolve in alcohol when dry, and let the solution evaporate spontaneously. *Robiquet*.

Prop. A white, crystalline mass, acquiring a blue color by exposure to air. The aqueous solution is decomposed by boiling into cyanohydric acid, and a white precipitate becoming blue by exposure.

Ferrocyanides. They are all decomposed when exposed to a red heat in close vessels; those with an alkaline metal giving rise to the formation of cyanide of that metal, carburet of iron, and evolving nitrogen gas; all others yield mixtures of metals and metallic carburets, with or without the evolution of cyanogen. All the soluble ferrocyanides are decomposed by being boiled with oxide of mercury into cyanide of mercury, free alkali, and oxy-cyanide of iron. The ferrocyanides of potassium and sodium are converted by being calcined in open vessels into alkaline cyanates, and the sesqui-oxide or carburet of iron. Most of the ferrocyanides contain water of crystallization, which they lose when heated. Those

of zinc, copper, and mercury unite with ammonia to crystalline double compounds. (*Bunsen*.) Most of them are soluble in concentrated sulphuric acid without decomposition; or they unite with it, and lose their color. By nitric acid they are decomposed, many of them evolving cyanogen and forming metallic ferridcyanides. When those which are soluble in water are boiled with dilute acids, the ferrocyanohydric acid is separated, and at that temperature decomposed into cyanohydric acid which escapes, and into white cyanide of iron, which absorbs oxygen and becomes blue by exposure.

2. *Ferrocyanide of Potassium*. Syn. Prussiate of Potash. *Ger.* Blutlaugensalz. Form. 2 KCy, FeCy + 3 HO. For its preparation see the manufacture of prussiate of potash, above given. *Prop.* Crystallizes in large quadrangular tables or short prisms with truncated edges and angles of the square prismatic system, of a lemon-yellow color; spec. grav. 1.832; has at first a sweetish bitter, but afterwards saline taste; permanent in air, loses at 212° 12.82 pr. ct. = 3 eq. water, and becomes white; soluble in 4 pts. of cold and in 2 pts. of boiling water; insoluble in alcohol, by which it is precipitated from its aqueous solution in brilliant yellow flakes. Is converted by nitric acid, with the escape of cyanogen, and by chlorine, into the ferridcyanide of potassium. At a red heat it is decomposed into the carburet of iron and cyanide of potassium, but by the presence of air cyanate of potassa is formed.

It is largely employed in the manufacture of Prussian blue, in dyeing and color-printing, (farther as a qualitative analytic test), and for making nearly all the compounds of cyanogen. The commercial article is generally very pure.

3. *Ferrocyan. of Sodium*. 2 NaCy, FeCy + 12 HO. Prepared by boiling Prussian blue with carbonate of soda, crystallizes in yellow 4-sided prisms, effloresces in air, is soluble in 4.5 pts. cold water, insoluble in alcohol.

4. *Ferrocyanide of Ammonium*. 2 NH₄Cy, FeCy + HO. Formed by digesting ferrocyanide of lead with carbonate of ammonia, and precipitating with alcohol or evaporating. Yellowish white crystals, isomorphous with the salt of potassium, (2), permanent in air, very soluble in cold, decomposed by boiling water into cyanide of ammonium and a cyanide of iron. It forms a double salt with salammoniac by boiling equal pts. ferrocyanide of potassium and salammoniac with 6 pts. water; the crystals are 2 NH₄Cy, FeCy + NH₄Cl + 3 HO.

5. *Ferrocyanide of Barium*. 2BaCy , $\text{FeCy} + 6\text{HO}$. By digesting Prussian blue in a solution of caustic baryta, it deposits from the boiling hot solution in small yellow rhomboidal crystals, effloresces, soluble in 100 pts. hot, 1920 pts. cold water, also in sulphuric acid. A quadruple salt of, (2) and (5), ferrocyanide of barium and potassium, obtained by crystallizing the mixed salts, is 2KCy , $\text{FeCy} + 2\text{BaCy}$, $\text{FeCy} + 6\text{HO}$. The *strontium*-salt is similar to that of barium.

6. The *calcium*-salt, obtained similarly to that of barium, but with lime and water, forms lemon-yellow, very soluble crystals of the composition 2CaCy , $\text{FeCy} + 12\text{HO}$. The quadruple salt of calcium is anhydrous, 2KCy , $\text{FeCy} + 2\text{CaCy}$, FeCy . The double and quadruple salts of *magnesium* are anhydrous, the former deliquescent. The double salts of the *earths* are white, otherwise but little known.

7. The precipitates formed by ferrocyanide of potassium with solutions of the metals proper, are, with silver, mercury, bismuth, tin, lead, zinc, and manganese, white, but that of silver blues in drying, that of mercury while still in solution, that of manganese becomes peach-red; with nickel, greenish white; chrome, grayish green; with cobalt, green, becoming reddish; with copper and uranium, brownish red; molybdenum, dark brown. The quadruple cyanide of zinc, examined by Mosander, may be written 2KCy , $\text{FeCy} + 3(2\text{ZnCy}$, $\text{FeCy}) + 12\text{HO}$.

Ferridcyanides. 1. *Ferridcyanohydric Acid*. *Ger.* Rothe eisenhaltige Blausäure. *Form.* 3HCy , Fe_2Cy_3 , (*Cfdy*, H_3 , *Liebig*.) By passing sulphuretted hydrogen through fresh ferridcyanide of lead, or by the careful use of dilute sulphuric acid, filtration, and spontaneous evaporation, crystals are deposited of an astringent acid taste.

2. *Ferridcyanide of Potassium*. *Syn.* Red Prussiate of Potash. Discovered by L. Gmelin. *Form.* 3KCy , Fe_2Cy_3 . *Prep.* Pass chlorine gas through a solution of ferrocyanide of potassium, until it no longer gives a blue precipitate with persalts of iron; evaporate the solution, purify the crystals from chloride of potassium by re-crystallization. $2(2\text{KCy}$, $\text{FeCy}) + \text{Cl} = 3\text{KCy}$, $\text{Fe}_2\text{Cy}_3 + \text{KCl}$.

Prop. Transparent right-rhombic prisms of a red color and high lustre, anhydrous, permanent in air, soluble in 3·8 pts. cold, but more in hot water; the crystals burn in the flame of a candle with brilliant scintillations; heated in close vessels, cyanogen and nitrogen are evolved, a mixture of carburet of iron and ferrocyanide of potassium remains. The aqueous solution is decomposed by hydrochloric or hydrosulphuric acid; in the last case, sulphur and cyanide of iron are precipitated, and ferrocyanide of potassium and prussic acid are Ferridcyanide of iron (Turnbull's or Paris blue).... 3FeCy , Fe_2Cy_3

Biferridcyanide of iron (neutral blue)..... 3FeCy , $2\text{Fe}_2\text{Cy}_3$

Biferridcyanide of iron } (basic blue) 3FeCy , $2\text{Fe}_2\text{Cy}_3 + \text{Fe}_2\text{Cy}_3$, Fe_2O_3
and oxy-ferridcyanide }

Biferridcyanide of iron } 3FeCy , $2\text{Fe}_2\text{Cy}_3 + 2\text{KCy}$, FeCy
and ferrocyanide of iron }

ditto. } (soluble blues) $3(3\text{FeCy}$, $2\text{Fe}_2\text{Cy}_3) + 2(2\text{KCy}$, $\text{FeCy})$

ditto. } 3FeCy , $2\text{Fe}_2\text{Cy}_3 + 2(2\text{KCy}$, $\text{FeCy})$

Pelouze's ferroferridcyanide..... FeCv , $\text{Fe}_2\text{Cy}_3 + 4\text{HO}$.

formed. It is one of the most delicate tests for the protoxide of iron, with which it forms a precipitate similar to Prussian blue; peroxide of iron is not precipitated.

PRUSSIAN BLUES. 3. When a protosalt of iron is added to ferrocyanide of potassium in solution, so that a portion of the latter remains undissolved, the white precipitate of ferrocyanide of potassium is exposed to the air, from which it absorbs oxygen and becomes blue; having the form. 3FeCy , $2\text{Fe}_2\text{Cy}_3 + \text{Fe}_2\text{O}_3$. It is *basic Prussian blue*, or oxy-ferridcyanide of iron and Prussian blue, 3FeCy , $\text{Fe}_2\text{Cy}_3 + \text{Fe}_2\text{Cy}_3$, Fe_2O_3 . After dissolving out all other salts, it becomes soluble in water, without leaving a residue, forming a deep blue and rather permanent solution, precipitable by a salt, not by alcohol, and redissolving in water for the greater part. Its formation is prevented by the presence of strong acid. There is always a portion of sesquicyanide of iron formed by oxidation in the air, which tends to form a quadruple salt with ferrocyanide of potassium; but the greater part of the latter may be removed by washing.

Soluble Prussian blue. When a persalt of iron is added to an excess of ferrocyanide of potassium, and the salts are washed away from the precipitate, the latter dissolves with a deep blue color, which, on evaporation, yields nearly 2KCy , $\text{FeCy} + 3\text{FeCy}$, $2\text{Fe}_2\text{Cy}_3$, or 1 eq. each of Prussian blue and ferrocyanide of potassium. It is precipitable by salts, acids, and alcohol, and hence differs from the preceding basic compound. Evaporated in the air, and treated with (86 pr. ct.) alcohol, the blue compound, still soluble in water, is $2(2\text{KCy}$, $\text{FeCy}) + 3(3\text{FeCy}$, $2\text{Fe}_2\text{Cy}_3)$. The insoluble part remaining in Prussian blue, prepared with an excess of iron persalt, is 2KCy , $\text{FeCy} + 2(3\text{FeCy}$, $2\text{Fe}_2\text{Cy}_3)$. We have thus 3 compounds containing 2, 3, and 4 eq. Prussian blue respectively to 2 eq. ferrocyanide of potassium.

When a neutral solution of pernitrate or perchloride of iron is added to yellow prussiate of potash, the iron-salt not being in excess, Berzelius's *Neutral Prussian blue* is precipitated with the form. 3FeCy , $2\text{Fe}_2\text{Cy}_3$. It may be termed biferridcyanide of iron.

Another ferridcyanide of iron, prepared by precipitating protosulphate of iron by ferridcyanide of potassium, or by ferrocyanide, hypochlorite of soda, and muriatic acid, has a brilliant blue color, is decomposed by boiling with ferrocyanide of potassium, into ferridcyanide of potassium, and an insoluble gray residue of ferrocyanide of iron and of potassium. *Form.* 3FeCy , Fe_2Cy_3 , corresponding to the salt of potassium.

The following table comprises the above compounds.

Prep. of Prussian Blue. From what has been stated, the Prussian blues of commerce vary in constitution according to the mode of manufacture, and most of them are mixtures of the above described compounds. The purest is that obtained by the use of red prussiate of potash and pure copperas, forming ferridcyanide of iron, but there is a more economical method of obtaining an equally fine blue, which is a mixture of the preceding with common Prussian blue, and may have the form. 3 FeCy , $\text{Fe}_2\text{Cy}_3 + 3 \text{ FeCy}$, $2 \text{ Fe}_2\text{Cy}_3$, or 2 FeCy , Fe_2Cy_3 . To prepare it, dissolve 6 pts. green vitriol, freed from copper by metallic iron, and 6 pts. yellow prussiate of potash in 15 pts. water separately, mix the solutions, add 1 pt. oil of vitriol and 24 pts. strong muriatic acid with constant stirring, and after some hours add a clear solution of 1 pt. chloride of lime in 80 pts. water in successive portions, until the escape of chlorine produces effervescence. After some hours wash thoroughly with water or digest with nitric acid, and dry the blue product. (*Hochstetter.*) The copperas solution may be divided into two parts, one of which is peroxidized by chloride of lime or soda, then mixed with the other, and this mixed proto- and persalt treated with yellow prussiate. By precipitating perntrate or perchloride of iron by yellow prussiate, not in excess, Berzelius's neutral blue is precipitated.

For the cheaper kinds of blue, copperas (calcined or not), yellow prussiate of potash and alum are employed. The yellow prussiate is sometimes taken after the first or second lixiviation of the melted mass, a little sulphuric acid being used at the same time to neutralize free potassa. The precipitate is carefully drained and repeatedly washed during free exposure to air, and the excess of iron removed by sulphuric acid. This Prussian blue contains several of the blues above enumerated together with alumina.

Prop. The better qualities are light and porous, of an exceedingly rich, velvety, violet-blue color, with a glimmering copper-red color and lustre on a freshly broken surface. The inferior qualities exhibit a less brilliant blue color, although often a higher copper-red lustre where they have been dried at a high temperature. It is insoluble in water and dilute acids. It is decomposed when heated in close vessels into water, prussic acid, carbonate of ammonia, and carburet of iron; heated in air it burns slowly, leaving oxide of iron (and earthy matters, if present). It is decomposed by strong prussic and fuming nitric acids, the former liberating ferrocyanohydric acid. Sulphuric acid forms a white paste with it. Oxalic and other organic acids dissolve it, forming a beautiful deep blue solution, employed as blue ink. Alkalies decompose it into soluble ferrocyanides and sesquioxide of iron. Prussian blue is largely employed as a pigment in oil and water colors; for printing woven fabrics, by grinding it with muriatic acid and thickening; or for spirit colors, by grinding with a solution of perchloride of tin and thickening. For blue figures, apply the mordant of proto- or peracetate of iron, thickened

with gum, and after drying pass through a solution of prussiate of potash acidulated with muriatic acid.

Chromo-cyanides. A class of salts, discovered by Bückmann. The chromo-cyanhydric acid, obtained from the salt of lead by sulphuretted hydrogen, forms soluble crystals. The potassium salt, obtained by evaporating caustic potassa with oxide of chrome and an excess of prussic acid, forms yellow crystals of the same form as the corresponding ferridcyanide. Form. 3 KCy , Co_2Cy_3 .

Cobaltid-cyanides. The cobaltid-cyanhydric acid, 3 HCy , Co_2Cy_3 , obtained from the lead salt by decomposition with sulphuretted hydrogen, filtration, and evaporation, forms colorless fibres, of a strong acid taste, deliquescent, very soluble. The salt of potassium, 3 KCy , Co_2Cy_3 , obtained by dissolving hydrate, carbonate, or cyanide of cobalt in cyanide of potassium with excess of prussic acid, forms yellowish crystals, isomorphous with the ferridcyanide, anhydrous, fusible, soluble, not decomposed by nitric, muriatic, or sulphuric acid, does not precipitate the salts of iron, but does those of protoxide of cobalt rose-red. The salt of lead is obtained by adding the preceding, and then ammonia, to acetate of lead, white, granular. The silver salt, similarly produced with nitrate of silver, is white, crystalline, soluble in ammonia, and forms with it prismatic crystals.

Nickel-cyanides. The general formula is 2 MCy , NiCy . The potassium salt, obtained by solution of fresh cyanide of nickel in cyanide of potassium, or by igniting metallic nickel with prussiate of potash, forms yellow rhombs with 1 eq. water. The sodium salt is yellow with 5 eq. water; those of ammonium barium, calcium yellow, with different quantities of water. By adding one of these soluble salts to the solution of a metal proper, double nickel-cyanides are obtained. They all correspond to the ferrocyanide.

Subcyanide of copper forms a series of compounds of which the potassium salt is obtained in yellow crystals from a saturated solution of cyanide of copper in cyanide of potassium. It precipitates protosalts of iron greenish yellow; salts of gold, yellowish green; of lead, light green; of manganese, zinc, and bismuth, light yellow.

Mercury-cyanides. Cyanide of mercury exhibits a strong tendency to form double salts. Besides the oxycyanide of mercury HgCy , 3 HgO , above described, Johnston describes another, HgCy , HgO . The cyanide of mercury also unites with haloid salts. Cyanide of mercury and chloride of potassium, HgCy , $\text{KCl} + \text{HO}$, formed by mixing the two salts, or by dissolving 1 pt. cyanide of potassium in 3 pts. chloride of mercury, forms white laminæ. The bromide double salts have the formula MBr , $2 \text{ HgCy} + \text{mHO}$, the salt with bromide of potassium having 4 eq. water, with that of sodium 3 eq., with those barium and strontium 6 eq. water. The double salt, with iodide of potassium, KI , 2 HgCy , is formed direct from saturated solutions. Cyanide of mercury also forms a yellow, crystallizable double salt with chromate of potassa.

Cyanide of silver forms a series of soluble double salts with cyanides of potassium, sodium, ammonium, barium, strontium, and calcium, by direct solution, precipitable by alcohol. The solutions added to many other metallic salts produce the insoluble double cyanides. They are mostly white.

Platino-cyanide of potassium, obtained by heating nearly to ignition platinum sponge and dry prussiate of potash in a glass flask, and extracting with water, or by adding concentrated chloride of platinum to saturated cyanide of potassium, and boiling to dissolve the precipitate, forms thin rhombic prisms, yellow by transmitted, blue by reflected light. Form. $\text{KC}_y, \text{PtC}_y + 3 \text{HO}$. Its solution precipitates solutions of zinc, tin, silver, mercury, white; copperas, bluish white; perchloride of iron, brownish red; blue vitriol, greenish blue. An analogous salt is obtained in a similar manner from powdered iridium, but does not exhibit the peculiar play of color. By passing chlorine through the platino-cyanide in solution a salt is formed, according to Knop, in copper-red needles of the composition $2 \text{KC}_y, \text{Pt}_2\text{C}_{y_3} + 5 \text{HO}$; (?) it precipitates silver and mercury white; copper, greenish white; suboxide of mercury, blue.

Aurocyanide of potassium, obtained by treating fulminating gold (from 7 pts. gold) with 6 pts. cyanide of potassium in solution, forms crystals with the formula $\text{KC}_y, \text{AuC}_y$. The auridecyanide is obtained by dropping a concentrated solution of perchloride of gold into a concentrated hot solution of cyanide of potassium. The efflorescent, white crystals have the formula $2 (\text{KC}_y, \text{AuC}_y) + 3 \text{HO}$. It forms other auridecyanides by precipitation.

CYANOGEN AND OXYGEN.

Cyanogen forms three acids by union with oxygen, in each of which there is 1 eq. of each element. They are only known in combination with water or with bases, and have the formula $\text{CyO}, \text{Cy}_2\text{O}_2, \text{Cy}_3\text{O}_3$.

1. *Cyanic Acid.* $\text{C}_2\text{N}, \text{O} + \text{HO} = \text{CyO}, \text{HO}$. Formed by passing cyanogen over carbonate of potassa at a red heat, by the action of the air on heated cyanogen compounds with the presence of fixed alkali. Prepared by distilling cyanuric acid, and collecting in an ice-cooled receiver. A clear liquid, of a strong, penetrating odor, similar to that of acetic or formic acid, reddens litmus, decomposes rapidly into cyamelide, mixes readily with water, and decomposes rapidly into bicarbonate of ammonia, $\text{C}_2\text{NO}, \text{HO} + 2 \text{HO} = \text{NH}_3, 2 \text{CO}_2$. Its alkaline salts are soluble, the rest insoluble; its fixed alkaline salts decompose by boiling into ammonia and carbonates. Their formula is MO, CyO .

Cyanic and Chlorohydric Acids. When dry muriatic acid gas is passed over dry cyanate of potassa in a tube or retort, a colorless liquid distills over, which does not decompose rapidly like cyanic acid, is converted by heat into cyamelide and chlorohydric acid. Form. $\text{CyO}, \text{HO} + \text{HCl}$, or more probably, $\text{CyCl}, 2 \text{HO}$, hydrated chloride of cyanogen. *Wöhler.*

Cyamelide, or Insoluble Cyanuric Acid, is the white, porcelain-like body which forms in

cyanic acid; it is insoluble in dilute acids, water, alcohol, and ether; is decomposed by alkalis into cyanate and cyanurate, ammonia being evolved; heated with strong, sulphuric acid, it is dissolved, and with 2 eq. water is resolved into carbonic acid and ammonia; by distillation it yields cyanic acid. Form. $\text{C}_2\text{O}_2 + \text{NH}$, or $\text{C}_2\text{N}, \text{O} + \text{HO}$. (?)

Cyanate of potassa is formed by calcining prussiate of potash in fine powder exposed to the air, or a mixture of 3 pts. of the same with 1 pt. dry pearlash and 4 pts. of pure binocide of manganese in a crucible, or by fusing cyanide of potassium in a Hessian crucible, adding litharge as long as the latter is reduced, and heating highly to collect the lead in one mass, or by kindling the latter mixture by a red-hot body, then by solution in boiling alcohol, from which it crystallizes on cooling in transparent plates, which change by moisture, spontaneously, or by heat, into bicarbonate of potassa and ammonia, and by the action of acetic or dilute mineral acid, cyanurate of potassa is precipitated. Cyanate of ammonia, formed by bringing the 2 dry gases together, is a white woolly body, easily decomposed by acids or alkalis; if gently warmed, with or without water, or exposed to the air, ammonia is given off and UREA produced. Cyanate of baryta is formed together with cyanide by passing cyanogen into milk of baryta, and decomposing the cyanide by carbonic acid. The cyanates of lead and silver, obtained by precipitation with cyanate of potassa, are white. The latter dissolves in ammonia, and forms cyamelide with sulphuretted hydrogen.

2. *Fulminic Acid.* *Ger.* Knallsäure, *Paracyansäure*. Unknown in its pure or hydrous state, shown by Gay-Lussac and Liebig to be a constituent of fulminating silver and mercury, and formed when nitrate of silver or subnitrate of mercury with excess of nitric acid are boiled with alcohol. If nitrous acid vapor be passed into a solution of nitrate of silver in alcohol, fulminate of silver precipitates, whence the change may be thus illustrated, $2 \text{NO}_3 + \text{C}_4\text{H}_6\text{O}_2 = \text{C}_4\text{N}_2\text{O}_2 + 6 \text{HO}$. It may be regarded as a bibasic acid, with the general formula $2 \text{MO}, \text{Cy}_2\text{O}_2$, in which in the acid salts or bifulminates 1 eq. MO is replaced by HO , thus, $\text{MO}, \text{HO} + \text{Cy}_2\text{O}_2$, and in the double salts $\text{MO}, \text{M'O} + \text{Cy}_2\text{O}_2$.

Fulminate of Mercury. *Syn.* Fulminating Mercury. *Ger.* Knallquecksilber. Discovered by Howard. *Prep.* Dissolve 1 pt. mercury in 12 pts. nitric acid (of spec. grav. 1.36), when cool add to the solution 11 pts. alcohol (of 80 to 85 pr. ct.), heating in a water-bath until it becomes cloudy; the violent effervescence on removal from the fire is diminished by adding alcohol gradually; metallic mercury is precipitated, nitric ether evolved, and crystals deposited, which may be purified by recrystallization from a hot solution. *Prop.* Form. $2 \text{HgO}, \text{Cy}_2\text{O}_2$. Fine, white, silky crystals, exploding violently when struck or rubbed between hard surfaces, deflagrating on live coals, with a slight explosion and a blue flame. From its liability to explosion by accidental friction or otherwise, great caution should be used in its preparation and use. It

is employed for filling the heads of percussion caps, being ground to fine powder with water on a marble surface with a wooden roller and then mixed with saltpeter. Other mixtures are also used containing chlorate of potassa and sulphur. When digested with caustic alkali, the latter replaces one half of the suboxide of mercury and double salts are formed of a yellow color, detonating. The salt of suboxide of mercury, obtained by precipitation, is less explosive.

Fulminate of Silver, prepared like the salt of mercury, with a little less nitric acid, and twice as much alcohol, forms fine white crystals of a high lustre, sparingly soluble in cold, soluble in 36 pts. boiling water; it explodes more violently than the preceding, by a blow, friction, the electric spark, or oil of vitriol, and more readily after exposure to sunlight, is not decomposed by nitric acid; caustic and muriated alkalies separate one half of the silver, the former as oxide, the latter as chloride, and crystalline salts with two bases are obtained, from which nitric acid separates the bifulminate of silver. The neutral salt has the formula $2 \text{AgO}, \text{Cy}_2\text{O}_2$; the acid salt, $\text{AgO}, \text{HO} + \text{Cy}_2\text{O}_2$, is a white powder, scarcely soluble in cold, very soluble in boiling water, and very explosive. The fulminate of silver and potassa is white, crystalline, soluble in 8 pts. boiling water, explosive, with the formula $\text{KO}, \text{CyO} + \text{AgO}, \text{CyO}$, or $\text{KO}, \text{AgO}, + \text{Cy}_2\text{O}_2$. The salt of soda is reddish brown, more soluble; that of ammonia very explosive, and by solution in ammonia a basic salt separates, far more explosive than fulminating silver; those of baryta and strontia are white, sparingly soluble, of lime yellow soluble, of magnesia one is rose-red, not explosive, the other white, explosive.

Fulminates of copper or zinc may be prepared by digesting fulminates of mercury or silver with metallic copper or zinc. The former forms green crystals, soluble and explosive; the latter treated with baryta forms $\text{ZnO}, \text{BaO} + \text{Cy}_2\text{O}_2$, and this again decomposed by sulphuric acid leaves in solution, $\text{ZnO}, \text{HO}, + \text{Cy}_2\text{O}_2$, or the bifulminate of zinc.

3. *Cyanuric Acid*. Cyanurensäure, (*Berzelius*). *Prep.* Formed from the decomposition of solid chloride of cyanogen by water, of the soluble cyanates by dilute acids, of urea by heat, by the distillation of uric acid and of melam, melamine, ammelide, and ammeline by acids. 1. Dissolve dry melam in strong sulphuric acid, by aid of a gentle heat, throw the solution into 20—30 pts. water; keep the mixture for several days near boiling, until upon trial it no longer gives a white precipitate with ammonia; evaporate to crystallize, and purify by a re-crystallization. It first forms ammelide and ammonia by taking up water, and ammelide then forms cyanuric acid and ammonia, thus $\text{C}_{12}\text{N}_{11}\text{H}_9 + 6 \text{HO} = \text{C}_3\text{N}_3\text{H}_3\text{O}_3 + 2 \text{NH}_3$, and then $\text{C}_{12}\text{N}_9\text{H}_9\text{O}_6 = 2(\text{C}_3\text{N}_3\text{O}_3) + 3 \text{NH}_3$. 2. Heat urea beyond its fusion, until it is converted with the evolution of ammonia into a white or grayish white dry mass: dissolve this in concentrated sulphuric acid, treat the solution with nitric acid added drop by drop until it becomes colorless, and then

add it to an equal volume of water; when cold, crystals of pure cyanuric acid are deposited.

Prop. Colorless, inodorous, a slight taste, sparingly soluble in cold, soluble in 24 pts. boiling water; the oblique rhombic prisms from the aqueous solution contain 4 eq. water, which they lose at common temperatures when exposed to the air, but more rapidly when heated, and then the dry acid contains 3 eq. of water; it may be obtained in crystals free from crystal. water from a hot saturated solution in nitric or chlorohydric acid. The hydrate, when heated, is converted into 3 eq. of hydrated cyanic acid. It is soluble in the strongest acids without decomposition, but by long-continued boiling is converted into ammonia and carbonic acid. Its salts have the general formula $3 \text{MO}, \text{Cy}_3\text{O}_3$, that of a tribasic acid; they are all crystalline, decomposed by acids, cyanuric acid crystallizing out of the solution: the alkaline salts are fusible by heat, and form then an alkaline cyanate.

Cyanurate of potassa, made by neutralizing a boiling saturated solution of the acid in potassa, forms white cubes, $\text{KO}, 2 \text{HO} + \text{Cy}_3\text{O}_3$. By dissolving these crystals in caustic potassa, alcohol precipitates $2 \text{KO}, \text{HO} + \text{Cy}_3\text{O}_3$ in white acicular crystals. The salt of ammonia forms white, lustrous prisms, efflorescent. One salt of baryta, formed by dropping barytic water into a boiling solution of the acid, leaving the latter in excess, forms small prisms, $\text{BaO}, 2 \text{HO} + \text{Cy}_3\text{O}_3 + 2 \text{HO}$; but by pouring the acid into an excess of barytic water, or by mixing chloride of barium and a boiling solution of the acid, there is formed $2 \text{BaO}, \text{HO} + \text{Cy}_3\text{O}_3 + 2 \text{HO}$. The salt of lead is obtained by mixing a boiling solution of the acid with subacetate of lead; white, pulverulent; form. $3 \text{PbO}, \text{Cy}_3\text{O}_3 + 2 \text{HO}$. The silver-salt, obtained from nitrate of silver and either of the salts of potassa, is white, pulverulent, with the form. $2 \text{AgO}, \text{HO} + \text{Cy}_3\text{O}_3$, but if a silver solution be added to a boiling solution of cyanurate of ammonia, the precipitate is $3 \text{AgO}, \text{Cy}_3\text{O}_3$, or isomeric with the cyanate of silver.

4. *Hypocyanous Acid*. Syn. Paracyanic acid, (*Johnston*). Obtained by solution of paracyanogen in nitric acid and precipitation by water, is yellow, amorphous, reddens litmus, unites with bases to salts, and is composed of $\text{C}_8\text{N}_4\text{O} = \text{Cy}_4\text{O}$.

Cyanogen and Halogens. 1. *Gaseous Chloride of Cyanogen*, formed when chlorine is passed into prussic acid, when moist cyanide of mercury is placed in an atmosphere of chlorine in the dark, or when mellon is heated in dry chlorine, is gaseous at common temperatures, has a most powerful penetrating odor, becomes solid at 0° , and forms long acicular prisms, which fuse at 5° , and boil at 10° . If the liquid be introduced into glass tubes and hermetically sealed, it is gradually converted into the solid chloride. It is decomposed by the alkalies; protosalts of iron are made deep green when an alkali is added to the mixture. If moistened cyanide of mercury in chlorine be exposed to solar light, a heavy oily liquid of a yellow color is formed, insoluble in water, and with

the same odor as the gaseous chloride; the same substance appears to be formed by chlorine and fulminate of silver. If its solution in alcohol be thrown into water, a crystalline substance, like camphor, is precipitated; on exposing a mixture of moist chlorine and chloride of cyanogen gases to the sun's rays, two other solid compounds appear to be formed. Form. CyCl . (?)

2. *Solid Chloride*. Formed by exposing dry chlorine gas and anhydrous cyanohydric acid to the sun's light; chlorohydric acid and the solid chloride are formed, the latter in crystals. When pure, it is white, sublimes in crystals, with a penetrating odor similar to the excrement of mice, and a sweet biting taste; spec. grav. = 1.32; fuses at 284° , sublimes at 374° , soluble in absolute alcohol and ether. By digestion in water at a gentle heat, it is resolved into cyanuric and chlorohydric acids, whence its probable formula Cy_2Cl_3 .

3. *Bromide of Cy*. CyBr . Add 1 pt. bromine to 2 pts. cyanide of mercury, and when the first heat of union has diminished distil at a gentle heat. White cubical crystals condense, which are gaseous at 60° , soluble in water and alcohol, of a strong odor.

4. *Iodide of Cy*. CyI . Distil cyanide of mercury, iodine, and water. White fibrous crystals soluble in water, alcohol, and ether, of a strong odor, volatile at 100° .

Cyanogen and Sulphur. There are two compounds of sulphuretted hydrogen and cyanogen, and a series of sulphocyanides. The latter gives rise to mellon, cyanilic acid, melamin, ammeline, &c.

1. One of the compounds with sulphuretted hydrogen is produced by bringing together 2 vols. cyanogen with 3 vols. of the former in the presence of a little water, which absorbs them and deposits yellow acicular crystals, the solution of which is not precipitated by salts of lead. Form. $\text{C}_4\text{N}_2\text{H}_3\text{S}_3$, which may be written $2(\text{C}_2\text{NHS}) + \text{HS}$, or $2\text{Cy}, 3\text{HS}$, which makes it a lower sulphhydrate than the following. Völckel observes it may be viewed as Allantoin, with sulphur instead of oxygen. *Gay-Lussac*.

2. The other compound is prepared by conducting sulphuretted hydrogen into a saturated solution of cyanogen in alcohol, deposits on being cooled in bright orange-red crystals, insoluble in cold, slightly soluble in boiling water, very soluble in hot alcohol, soluble by alkalis in the cold, and precipitated unchanged by acids; but by heat a mixture of metallic sulphuret and sulphocyanide is formed; its solution precipitates salts of silver, lead, and copper; the compound, with silver is decomposed when gently heated into sulphuret of silver and free cyanogen. (*Wöhler*.) Formula $\text{Cy}, 2\text{HS}$, or $\text{C}_2\text{NHS}, \text{HS}$. *Völckel*.

Rhodanides. Sulphocyanides. There is a series of compounds analogous to cyanides, but containing sulphur, in which there is assumed a radical *Sulphocyanogen*, called by Berzelius *Rhodanogen*, from *rhodon*, red, from its red color with persalts of iron.

The radical was supposed to have been isolated by Liebig, but the constitution of this body has been more accurately studied by

Parnell and Völckel, who have given a totally different formula for its composition from that of Liebig. The composition of the rhodanhydric or sulphocyanhydric acid might be represented by CyS_2, H , in whose compounds the H is replaced by a metal M, forming a rhodanide, but it may also be written CyS, HS , corresponding to hydrated cyanic acid, with sulphur instead of oxygen, forming sulphocyanates. Thus,

Hydrated cyanic acid..... = CyO, HO

Oxycyanate of lead..... = CyO, PbO

Rhodanhydric acid..... = CyS, HS

Rhodanide of lead..... = CyS, PbS

From the relation between sulphocyanides and cyanurates, Dumas observes that rhodanhydric acid might be tripled, thus, $\text{Cy}_3\text{O}_3, 3\text{HO}$ = cyanuric, and $\text{Cy}_3\text{S}_3, 3\text{HS}$ rhodanuric acid.

Rhodanhydric Acid. Syn. Hydrosulphocyanic Acid, Sulphuretted Chyazic Acid. Ger. Schwefelblausäure, Rhodanwasserstoffsäure. (*Berzelius*.) Occurs in the seeds and blossoms of Cruciferae, and in the saliva of man and sheep. *Gmelin*.

Prep. Nearly decompose rhodanide of lead by sulphuric acid, and the balance by sulphuretted hydrogen, or the salt of silver in 10 vols. water, wholly by the same gas.

Prop. A colorless, very acid liquid of strong odor; spec. grav. 1.022; boils at 217° , and crystallizes at 14° ; it decomposes spontaneously, forming a brown liquid, and finally deposits a yellow body; 30 grains of strong acid occasions sudden death, and smaller quantities produce strong effects, probably from the development of prussic acid.

Rhodanides, or Sulphocyanides. The acid being regarded as a hydracid, has the formula H, CyS_2 , and its metallic compound M, CyS_2 . The soluble salts are formed by the action of the acid on the metallic oxide, by passing cyanogen into solutions of alkaline persulphurets, or over them heated to redness, by heating or fusing the soluble cyanides with sulphur and insoluble cyanides with soluble sulphuret. The soluble salts impart a deep blood-red color to persalts of iron, for which they are a delicate test, but less so than the galls or ferrocyanides. By the action of nitric acid and chlorine, *metasulphocyanogen* is formed. The salts of metals proper are changed by a red heat into metallic sulphurets and mellon, usually evolving sulphur and sulphuret of carbon. Most rhodanides are soluble in water, those of potassium, calcium, and cobalt also in alcohol.

Rhodanide of Potassium. Two pts. prussiate of potash, gently roasted to expel water, are powdered, mixed with 1 pt. flowers of sulphur, and fused in an iron vessel at a low red heat, until the bubbles of gas burn with red light; the cold mass is dissolved in boiling water, treated with carbonate of potassa as long as it produces cloudiness, then boiled for $\frac{1}{4}$ hour, filtered, evaporated, and the crystals purified by resolution in alcohol. Form. K, CyS_2 , or KS, CyS . Long, colorless, anhydrous prisms, fusible, deliquescent, very soluble in hot alcohol.

The salt of ammonium, obtained by adding sulphuret of carbon to alcohol saturated with ammonia, or by saturating the acid with am-

monia and gently evaporating, forms a deliquescent white saline mass, which, when heated, evolves ammonia, then sulphuret of carbon, and lastly protosulphuret of ammonium; and if the heat be not carried too far, the residue is melam or melamin and mellan.

The salt of *lead*, obtained from the preceding and sugar of lead, forms yellow, opaque crystals, of high lustre, Pb, Cy S_2 . With subacetate of lead, a basic or oxyrhodanide is produced of a yellow color, $\text{Pb, CyS}_2 + \text{PbO}$. The *silver* salt from nitrate of silver is white, curdy, insoluble in water, soluble in ammonia, from which it crystallizes. The subsalt of *mercury*, obtained by dilute solutions of subnitrate of mercury and the potassium-salt, is a lemon-yellow powder, $\text{Hg}_2, \text{CyS}_2$, which decomposes by boiling into the following, Rhodanide of mercury, Hg, CyS_2 . When dried and heated it is resolved into sulphuret of mercury, bisulphuret of carbon and mellan. Ammonia produces in its solution a yellow precipitate, which, according to Gundelach, has the composition $\text{Hg}_2, \text{CyS}_2 + 3 \text{H}_2\text{O}$.

3. *Xanthanhydric Acid*. Syn. Persulphocyanhydric Acid. Form. CyS_2, HS , or CyS_3, H . By passing dry chlorohydric acid gas over rhodanide of potassium fused in a retort, the yellow acid sublimes; or to a saturated solution of the same salt add 6 or 8 times its volume of strong muriatic acid, let it repose for 24 hours, wash the fine crystals with a little water, and purify them by crystallization from alcohol or ether. Its formation from rhodanhydric acid is thus represented by Vöckel, $3(\text{H, CyS}_2) = 2(\text{H, CyS}_3) + \text{HCy}$. It acts like the preceding and sulphohydric acid in precipitating metallic salts. The salt from sugar of lead is Pb, CyS_3 , from subacetate of lead $2(\text{Pb, CyS}_3) + \text{PbO}$. The salts of mercury, copper, and proto-tin are yellow, of bi-platinum yellowish brown.

4. *Metasulphocyanogen*. Liebig's Sulphocyanogen. Prepared by saturating a strong solution of a metallic rhodanide with chlorine, or by heating it with nitric acid, it falls down as a light, yellow powder, insoluble in water, alcohol, and ether, soluble in strong sulphuric acid, and precipitable by water. Form. $\text{C}_{12}\text{N}_6\text{S}_{12}\text{H}_3\text{O}$. (Parnell.) $\text{C}_8\text{N}_4\text{H}_2\text{S}_6\text{O}$. (Vöckel.) According to the latter, it thus arises from rhodanhydric acid by chlorine, $4(\text{C}_2\text{NHS}_2) + \text{HO} + \text{Cl}_3 = \text{C}_8\text{N}_4\text{H}_2\text{S}_6\text{O} + 3 \text{HCl}$. From its solution in caustic potassa acids precipitate the hydrothiocyanic acid of Parnell.

5. *Mellan*. Mellone. (Liebig.) Formed when the preceding body, melam, ammelin, or ammeline, is heated to redness in a retort, or from rhodanide of potassium and chlorine, is a lemon-yellow powder, insoluble in water, alcohol, and dilute muriatic and sulphuric acids, with decomposition in nitric acid and caustic fixed alkali, unites directly with potassium, evolving light, with hydrogen to an acid, decomposes bromide, iodide, and sulphocyanide of potassium, eliminating their negative elements. Formula C_6N_4 . Its origin from metasulphocyanogen, may be thus symbolized by Vöckel's formula, $\text{C}_8\text{N}_4\text{S}_6\text{H}_2\text{O} = \text{C}_6\text{N}_4 + 2 \text{CS}_2 + \text{S}_3 + \text{HS} + \text{HO}$, the 3 first of which are among the products of distillation.

Melanhydric Acid, (Gmelin,) obtained by decomposition of the salt of potassium with muriatic acid, forms a white powder, insoluble in cold, slightly in hot water, insoluble in alcohol, ether, and oils, decomposes carbonates and acetates. Form. $\text{H, C}_6\text{N}_4$. *Mellanide of potassium*, prepared by fusing the rhodanide in a porcelain crucible at a red heat, and adding mellan until sulphur, &c., ceases to arise, or by fusing 5 pts. butter of antimony with 8 pts. rhodanide of potassium, forms white needles, scarcely soluble in cold, more so in hot water, lose crystal-water by heat, and fuse to a clear yellow glass. Its solution precipitates earthy and metallic salts. Form. $\text{K, C}_6\text{N}_4$. According to the recent observations of Laurent and Gerhardt, mellan does not play the part of a radical, but by the agency of potassa it forms mellonic acid (mellanhydric) by assuming 2 eq. water, becoming $\text{C}_6\text{N}_4\text{H}_2\text{O}_2$, that mellonate of lead might then be $\text{C}_6\text{N}_4\text{HO} + \text{PbO}$, that mellan has the composition $\text{C}_{12}\text{N}_9\text{H}_3$, and by combining with potassium ammonia is evolved, and the salt is composed of $\text{C}_6\text{H}_4\text{K}$. This view appears correct if ammonia be evolved; for $\text{C}_{12}\text{N}_9\text{H}_3 = \text{NH}_3 + \text{C}_{12}\text{N}_8$, which is the composition of mellan in the mellanides.

6. *Cyanilic Acid*. When mellan is long boiled with dilute nitric acid, the solution yields colorless crystals, which, from a resolution in hot water, are obtained in pearly tablets of the same composition as crystalline cyanuric acid, with 4 eq. water.

7. *Melam*. By dry distillation of rhodahydrate of ammonia, or a mixture of rhodanide of potassium and salammoniac, melam remains, mixed with chloride of potassium in the latter case. It is a white, amorphous powder, insoluble in water, alcohol, and ether, dissolved with decomposition in potassa, soluble in hot and strong sulphuric and nitric acids, from which alcohol and water throw down ammeline. If the acid solutions be boiled for some time, it is converted into cyanuric acid and ammonia. By boiling with dilute muriatic or nitric acid, or with potassa, ammelin and melamin are formed. When heated, mellan is formed, and by potassium the mellanide of potassium; fused with potassa, ammonia and cyanate of potassa are formed. Form. $\text{C}_{12}\text{H}_{11}\text{O}_9$. (Liebig.) Its formation from 8 eq. of rhodanammonium is thus given: $8(\text{C}_2\text{NS}_2, \text{NH}_4) = 5 \text{NH}_3 + \text{S}_8 + 4 \text{CS}_2 + \text{C}_{12}\text{N}_{11}\text{N}_9$, (melam). According to Vöckel, and Laurent and Gerhardt, melam is composed of melamin and mellan.

8. *Melamin*. (Liebig.) Boil melam in dilute potassa to a clear solution, evaporate until crystals form, which increase on cooling, and purify by re-crystallization. Colorless, or yellowish rhombic 8-hedra, anhydrous, sparingly soluble in cold water, insoluble in alcohol and ether, sublimes partly unaltered, decomposed by hot and strong nitric or sulphuric acids, and by fusion with caustic potassa similarly to melam. Form. $\text{C}_6\text{N}_6\text{H}_6$. Melamin unites with dilute acids to form salts, of which the sulphate, phosphate, nitrate, and oxalate are less soluble than melamin, the acetate and formiate very soluble; it unites directly with anhydrous hydracids to anhydrous salts, with

oxacids only by assuming 1 eq. water. Its composition and behaviour might lead to the formula $C_6N_4, 2 NH_3$, mellan and ammonia.

9. *Ammelin.* (Liebig.) After the melamin has separated from the potassic solution above, ammelin separates by neutralizing with acetic acid, and is recrystallized from a nitric solution, as nitrate, which is precipitated by ammonia. White, silky needles, insoluble in alcohol and ether, soluble in alkalies, by long boiling in dilute acids, or by solution in oil of vitriol it is decomposed into ammonia and ammelid; by fusion with potassa, ammonia, and cyanate of potassa are formed. Its formation from melamin is thus shown, $C_6N_6H_6 + 2 HO = NH_3 + C_6N_5H_5O_2$. It unites with strong acids only to crystalline salts, and these again form double salts with metallic oxides; the nitrate fuses by heat, and leaves ammelid. Form. $C_6N_5H_5O_2$, which, from its weaker basic character, compared with melamin, might be written $C_6N_4, NH_3, 2 HO$.

10. *Ammelid.* Obtained by decomposing the preceding, 7, 8, 9, by strong acids, and purified from solution in nitric acid, is a white, amorphous powder, insoluble in water, alcohol, and ether, soluble in alkalies and strong acids, decomposed by acids into ammonia and cyanuric acid; its crystalline nitrate decomposes with water. Form. $C_{12}N_9H_9O_6$, (Liebig.) $C_6N_4H_4O_4$, (Gerhardt.) According to the formula of Liebig, it might be written $2 C_6N_4, NH_3, 6 HO$, or, by adopting Gerhardt's, $C_6N_4, 4 HO$.

The series from mellan (of Laurent and Gerhardt) may be thus represented,

Mellan.....	$(2 C_6N_4), NH_3$
Melamin.....	$= C_6N_4, 2 NH_3$
Ammelin.....	$= C_6N_4, NH_3, 2 HO$
Ammelid.....	$= C_6N_4, 4 HO$

By abstracting NH_3 , and adding 2 HO, cyanuric acid is formed $= C_6N_3H_3O_6$. By the distillation of metasulphocyanogen mellan is produced, by that of rhodanide of ammonium, mellan is also generated with melamin, the latter arising from a combination of mellan with a portion of the ammonia generated, $C_6N_4 + 2 NH_3 = C_6N_6H_6$. The presence of ammonia in melamin explains its basic character, the power of which is diminished by combination with mellan. The action of acids or alkali on melamin develops ammonia, and adds 2 eq. water, leaving ammelin; $C_6N_4, 2 NH_3 + 2 HO = C_6N_4, NH_3, 2 HO + NH_3$; the smaller quantity of ammonia explains its very feeble basic character. By the farther action of acids, ammonia is again developed, 2 eq. water more are assumed, and ammelide remains, $C_6N_4, NH_3, 2 HO + 2 HO = C_6N_4, 4 HO + NH_3$, the absence of the latter accounting for its want of basic properties. By the farthest action of acids, ammonia is again eliminated, and 2 eq. water more are added to form hydrated cyanuric acid, $C_6N_3, 4 HO + 2 HO = NH_3 + C_6N_3H_3O_6$, or $(C_6N_3, O_3 + 3 HO = C_7O_3, 3 HO)$.

Völkel submitted xanthanhydric acid to distillation at different temperatures, and obtained a series of new compounds possessing much interest. This acid decomposes partly, so that sulphur and rhodanhydric acid are produced,

and partly so that the sulphur passes off as sulphuret of carbon, and melamin remains. At 284° the former decomposition takes place. At 293° rhodanhydric acid passes off with a little sulphuret of carbon, and from the residue extracted by boiling with water, then by potassa and precipitated by acid, a brown body is obtained, of the composition $C_7H_4N_4S_6$, or $C_7H_3N_4S_6, H$, and termed by Völkel *Melen-sulfid*, but by Berzelius *Melanhydric acid*. At 302° the same bodies are developed, but from the residue is obtained, by potassa and acid, a yellow body (*porranhydric acid*) of the composition $C_3H_2N_2S_2$. It is formed by the decomposition of melanhydric acid, thus $C_7H_4N_4S_6 = 2 (C_3H_2N_2S_2) + CS_2$, the latter passing off. It is insoluble in water, alcohol, and ether, and the neutral lead salt is $Pb, C_3HN_2S_2$.

Between 302° and 356° rhodanhydric acid, sulphuret of carbon, and cyanhydric acid are evolved, and several new bodies remain. At 320° *phiaanhydric acid* remains after boiling with water, &c., composed of $C_8H_5N_6S_4$. It is dark-yellow, insoluble in water, alcohol, and ether, its yellow neutral lead-salt gives a corresponding composition to the acid. Between 338° and 356° the same products as before result, while *xythanhydric acid* remains, $C_{10}H_7N_3S_4$, (?) of a brownish color and insoluble as the preceding. From the solution of the residue in water, when the temperature is between 320° and 356° , several other bodies are obtained.

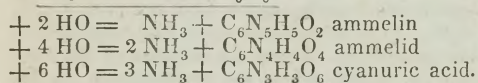
Between 356° and 392° the same products are evolved, but the xanthanhydric is now first wholly decomposed. The residue boiled with water gives a colorless solution, from which a white powder separates, or a brown solution, from which a brown powder is obtained; after evaporation a third body is produced. Cold potassa solution dissolves from the residue, insoluble in water, probably several bodies, while warm potassa solution dissolves from the last residue a new body, obtained in greater quantity at higher temperatures. At 437° the brown residue yields to boiling water several bodies similar to, but not the same as before; cold potassa solution extracts a brownish yellow body, and the hot solution dissolves *leucanhydric acid*. It is grayish white, insoluble as before, and consists of $C_8H_5N_5S_2$. Between 554° and 572° all the sulphur passes off as sulphuret of carbon, and melamin remains.

Völkel also submitted rhodanide of ammonium to distillation in a similar manner, and obtained a series of new products. This salt fuses, and begins to decompose at 401° , but soon ceases and does not form a continuous decomposition until between 500° and 518° . The volatile products are ammonia, then sulphuret of carbon, then sulphur, sulphurets, and rhodanide of ammonium. The residue is washed with cold, and then dissolved in boiling water, leaving a light-brown residue. The boiling yellow solution deposits a yellow body, *a*; the now colorless solution evaporated $\frac{1}{2}$ deposits *b*; and again evaporated $\frac{1}{2}$ deposits *c*, while the solution contains *d*, which was at first dissolved by the cold water. The yellow body, *a*, consists of 2 bodies, a yellow

and white. *b* is white, crystalline, soluble in boiling water and in alcohol, and its aqueous solution precipitates silver, mercury, copper, and zinc salts; it is *alphanhydric* acid, and is composed of $C_{10}H_{10}N_{10}S_2$. *c* resembles *b*, but is composed of $C_{12}H_{12}N_{12}S_2$, and is termed *phalanhydric* acid. *d* is composed of $C_{14}H_{14}N_{14}S_2$, and termed *phalanhydric* acid. *c* and *d* precipitate the same metals as *b*, except that *c* does not precipitate zinc vitriol. If the temperature be 572° , the residue contains, besides rhodanide of ammonium, *arganhydric* acid, of the formula $C_{16}H_{16}N_{16}S_2$, insoluble in alcohol, soluble in boiling water, the solution as before reddening litmus, and precipitating silver and mercury. Melamin begins to be formed at 572° . Between 590° and 608° , the last portions of sulphur are expelled, and melamin remains, which at a higher temperature is converted into *glaucon*, of a light gray color, composed of C_4HN_3 , formed from melamin, by the loss of ammonia. According to Laurent and Gerhardt, glaucon is identical with mellan.

Gerhardt thus represents the decomposing series, from melamin to cyanuric acid, by the assumption of water and evolution of ammonia.

1 eq. melamin, $C_3N_3H_3$



CYCLAMIN. See ARTHANATIN.

CYDONIN. The peculiar gum or mucilage of the Quince seeds, (*Cydonia vulgaris*), differs from *arabin*, in being at first scarcely affected by alcohol, and remaining unaltered by silicate of potassa, infusion of nut-galls, and oxalate of ammonia. Sulphuric acid colors it pink, and separates a frothy coagulum. Being soluble in cold and hot water, it is thus distinguished from *bassorin* and *cerasin*.

CYMOPHANE. See CHRYSOBERYL.

CYNAPIN. An alkaloid, existing in the *Aethusa Cynapium*, or Fool's Parsley. It is soluble in alcohol and water, insoluble in ether, and has an alkaline reaction; crystallizes in rhombic prisms, and forms a crystallizable salt with sulphuric acid.

CYNODIN. Prepared by repose from a concentrated decoction of the root of *Cynodon dactylon* forms colorless prisms, soluble in alcohol, but scarcely in cold water, its solution in the latter menstruum reddening litmus. Though resembling asparagin in many properties, it is probably different. *Semmola*.

CYPERUSCULENTUS. Syn. Rush-nut. *Fr.* Souchet Comestible. *Ger.* Erdmandel.

Semmola's analysis of the root gave

Oil.....	4.8
Albumen.....	1.5
Starch.....	22.4
Inulin.....	4.3
Gum.....	17.8
Sugar.....	12.5
Coloring matter.....	1.4
Salts of potash, lime, and magnesia, with silica.....	5.5
Fibre.....	21.0
Water and loss.....	8.8
	100.0

The oil, obtained by expression, is of a yellow color and aromatic taste; spec. grav. 0.918; is more soluble in ether than alcohol, burns better than olive oil, and is saponifiable, the olein component being in much larger proportion than the margarin.

CYPRINE. See INDOCRASE.

CYSTIC OXIDE. See URINARY Calculi.

CYTISIN. The active principle of the *Cytisus Laburnum*, extracted by alcohol, is a yellowish green bitter mass, precipitable from its solutions by basic acetate of lead and nitrate of silver. According to Peschier, it is identical with CATHARTIN.

D.

DADYL. *Chem.* The oily compound, $(C_{20}H_{16})$, formed when the crystalline camphor, $(C_{20}H_{17}Cl)$, produced by the action of hydrochloric acid gas upon oil of turpentine is heated with lime. See CAMPHEN.

DAGUERREOTYPE. *Tech.* The art of producing pictures by the action of solar light on a silver-surface, properly prepared by the halogen elements. The silvered copperplate is thoroughly cleansed by tripoli and rotten stone, moistened with water, polished by a clean charcoal buff, and silvered in a battery once or twice, being buffed between and at the close of the operations. It is next exposed to the vapor of iodine in a dry box, in a dark room, to form a light yellow coating by candlelight, then to bromine vapor, until it assumes a purplish hue, and lastly, enclosed in a case and transferred to the camera, which has been properly adjusted by a ground glass plate, so that a perfect image will appear on the plate. The slide of the case being withdrawn, the light is allowed to act as long as experience dictates as necessary, and the slide being replaced, the case is transferred to the mercury box in a dark room. This box is an iron vessel containing mercury slightly heated by a lamp, and the effect of the vapors is judged of by examining the picture at intervals after a few minutes' exposure. It is next washed by a solution of hyposulphite of soda, then with pure water, and the excess of the latter removed by evaporation with a spirit lamp. The picture is now complete, but in order to render it durable and give a richer tone to the lights, the plate is gilded by covering it with a mixed solution of hyposulphite of soda and chloride of gold, heating it until the tone of the picture changes, then washing and drying it. If the picture be imperfect, it should not be subjected to gilding, which renders the plate more difficult to cleanse.

The theory of the operation is, that the surface of the silver plate is coated by a thin film of bromide and iodide of silver, which is extremely sensitive to light, so that the rays from light-colored objects passing through the camera lenses, decompose the sensitive surface, in proportion to the amount of light and the nature of the color. By exposure to mercurial vapor, this metal attaches itself to the decomposed parts of the plate, and in a quantity proportional to the amount of decomposi-

tion. The unaltered surface is then washed off by hyposulphite of soda, in which iodobromide of silver is soluble, and the remaining surface becomes unalterable in light. But as mercury evaporates slowly, and the picture would become fainter by time, it is secured by amalgamating it with gold. Previous to the last operation the picture is easily brushed off, but after it, some friction may be used without material injury. That portion of surface from which the bromiodide is removed presents the original polished surface of pure silver, so brilliant that it appears black in every position except that in which rays of light are immediately reflected to the eye. Hence the picture is visible in every position but the latter, and consists in the contrast between the dark polished surface of silver, and the white mercurialized portions of the surface.

Although the process appears simple, yet to obtain perfect pictures, a multitude of minutiae demand the closest attention of the operator. Thus, if the finger has touched the surface of the plate, it should be recleaned by rotten-stone and tripoli; the buffs, kept perfectly clean, should be moved in straight lines, and used until every trace of other lines is removed; the plate is exposed for a certain length of time to both the iodine and bromine vapors, varying with circumstances; it is then exposed in the camera for a varying period of from 1 second to several minutes according to the state of the weather, the time of day, the nature of the lens, &c.; there is also much care required in mercurializing, washing, and gilding. The number of minute accessories requisite to form a perfect picture require lengthened experience, and although all may be regarded as important, the most essential are, having a very perfect camera and perfectly clean plates.

DAMMARA. *Tech.* A tasteless, inodorous, whitish resin from the East Indies. Is entirely soluble in the oils, and consists of two peculiar principles, which have not yet been accurately examined.

DAMP, CHOKER. *Mining.* The technical name given by well-diggers and workmen generally to carbonic acid gas, because, when inhaled, it immediately causes a spasmodic contraction of the glottis.

DAMP, FIRE. *Mining.* The carburetted hydrogen of coal mines.

DANBURITE. *Min.* Crystalline, yellow, vitreous; $H. = 7.5$. $G. = 2.83$. Chiefly composed of SiO_2 56 + CaO 28.3 + HO 8. (*Sheppard*.) It appears to be a mixture. *Dana*.

DATHOLITE. *Min.* Syn. Humboldtite, Botryolite. *Descrip.* Cryst. Oblique Rhombic, cleavage parallel to vert. prism; also columnar and granular. $H. = 5-5.5$. $G. = 2.99-3.34$. Color and streak white, sometimes colored; vitreous; transparent, translucent; brittle, with subconchoidal fracture.

Chem. relations. Yields water in a closed tube; swells and fuses on charcoal to a clear glass, coloring the flame green; soluble in borax and mic. salt, leaving a skeleton of silica in the latter, and enameling when heavily charged; fuses to a clear bead with gypsum; soluble in muriatic acid before or after ignition

and gelatinizing. Form. of datholite $3(CaO, BO_2) + 3CaO, 4SiO_2 + 3HO$; of botryolite $3(CaO, BO_2) + 3CaO, 4SiO_2 + 6HO$, the latter differing from the former in containing twice as much water.

Local. Arendal, Norway; Seissel Alp, Tyrol; Perthshire, Scotland; in U. S., Hartford, &c., Conn.; Bergen Hill, N. J.

DATURIN. *Chem.* Found together with STRAMONIN, in the seeds of the *Datura Stramonium*.

Prop. Fuses at 212° , and sublimes unaltered at a higher temperature. Is slightly soluble in water, and readily so in ether and alcohol, and can be obtained in prismatic, colorless crystals, by diluting its alcoholic solution with water. It forms crystallizable salts with the acids, is highly poisonous, and has the remarkable effect of greatly dilating the pupil of the eye.

DAVYNE. *Min.* Probably the same as CANCRINITE.

DECANTATION. *Chem.* The draining off the clear supernatant liquor from any subsident matter. In analyses this is done by placing a glass rod against the margin of the bell glass, which is gently inclined, and allowing the liquid to trickle in a regular stream from its end, without loss. See ANALYSIS, p. 170, fig. 17. For larger operations, a siphon is requisite. This process does away with filtration, for a precipitate, requiring frequent washing, is ready to receive a new water, so soon as a settling has taken place and the old solution is drawn off, and thus both time and labor are saved.

DECAY OF WOOD. *Chem.* A species of decay or EREMECAUSIS, peculiar to woods generally, when exposed to air and moisture. The effect is a destruction of the cohesion of their particles, and a consequent friability of structure. The rationale of the change is predicated upon different theories, either of which is too defective to supply a definitely correct explanation. The concomitance of fungi gives some reason for attributing that species, called "Dry rot," to the diffusion of their filamentous spawn throughout the surface of the wood, and this doubtless does have some connection with the phenomenon, but generally the incipient step is a chemical action, akin to fermentation, for in many instances of spontaneous decomposition of timber, no fungi are present, or at least not until the decay has far advanced. The results of the decomposition of wood, which consists of carbon and the elements of water, are HUMUS and MOULD, and the longer the operation of decay, the greater the proportion of carbon in the residue, and hence, according to Liebig, confirmed by Mayer's and Will's analyses. Sound oak wood, by disease and death, is transformed from $C_{36}H_{22}O_{22}$ into $C_{35}H_{20}O_{20}$, showing that for every two eqs. of hydrogen, oxidized by the air, one eq. of carbonic acid had separated. Now as woody fibre, under water or in dry air, remains unaltered for a very long period, but experiences, when moist, a transformation, immediately on contact with air, there is reason to infer that it converts the oxygen of the surrounding atmosphere into an equal volume of carbonic

acid, and thus becomes altered to a matter of loose, lifeless texture. The continuance of the decay until the removal of all the hydrogen, would reduce the above formula to C_{25} , but the affinity between the last portions of hydrogen and carbon is in such an increased ratio of force that the final result never occurs, in nature, under ordinary circumstances, though it is possible that under certain conditions the decay of lignin does proceed to this extreme point, and being then in a liquid state, is resolved by crystallization into the diamond.

The *mouldering* of wood is distinct from decay, and is caused by the action of water in the absence of air, the limited access of oxygen modifying the results, carbonic acid is evolved, and the elements of the water, by the action of a portion of oxygen, have become united with the wood in the same manner as when air is freely admitted. Consequently, mouldering is a putrefactive process, as well as one of decay, in the simultaneous progress of which, the oxygen of the air and the components of the water take part. But as the composition of mouldered wood varies, as the access of oxygen is more or less free, the decomposition of wood assumes two different forms accordingly. In both cases the carbonic acid is generated, and in the latter case a certain quantity of oxygen enters into chemical combination, but it is more than probable that in this process the oxygen of the water assists in the formation of carbonic acid; and doubtless to a similar mouldering process is attributable the transformation of vast forests of trees. For example, the white mouldering matter of oak wood, decomposed under water, contains $C_{33}H_{27}O_{24}$. This is derived by adding $5HO + O$ to oak wood ($C_{36}H_{22}O_{22}$), and subtracting $3CO_2$. Liebig.

The decay of wood is retarded by a surrounding medium of carbonic acid, so as to prevent the access of air, and consequently of oxygen, and by antiseptics generally. Alkalies and alkaline earths facilitate decay, and hence the destructive power of moist sandy soils is due to their alkaline ingredient. Acids have a contrary effect.

Lignin, which is the basis of woody fibre, combines with certain salts, and it is this property, and that of the coagulability of the albumen of the sap, and destruction of the fungi by such means, which renders the application of saturated solutions of corrosive sublimate, sulphate of copper, acetate of iron, creasotic liquors, &c., preventives of dry rot in timbers. The use of chloride of mercury was first suggested by Kyan, but for practical purposes it is being superseded by Payne's plan of charging the pores of wood with a solution of chloride of calcium, and decomposing it into a sulphate of lime by the forcible injection of dissolved sulphate of iron. The deposition of particles of insoluble gypsum in the body of the wood renders it as hard as stone.

Boucherie (*Annal. de Chem.* lxxiv., 113) has found that wood may be completely impregnated with saline matters, by aspiration from the base of the trunk of the tree immediately after being felled. *Jour. Fr. Inst.*

DECOCTION. *Phar. Chem.* From decoquo

(*Lat.*) to boil. The extraction of vegetable or animal matters by boiling them with water; it is also applied to the solution itself. The aqueous solution of such organic matters as can be extracted from bodies without ebullition, is termed **INFUSION**. When active organic principles are soluble in cold water, it is often improper to boil them, for heat, in many instances, either volatilizes or decomposes them. See **DISPLACEMENT**.

DECOMPOSITION. *Chem.* The resolution of a compound body, by chemical means, into its proximate or ultimate constituents; or both, and is in contradistinction to *division*, which is a mere mechanical separation of a substance into lesser integral portions, each of which is of the same composition as previous to subdivision. See **AFFINITY** for *single* and *double* decomposition.

DECREPITATION. *Chem.* The crackling sound accompanying a fragmentary disintegration of certain crystallized substances when thrown upon ignited coals. The imperfect manner in which the outer covering of crystals conducts heat, causes their sudden expansion, and that of the particles of water mechanically incorporated in their texture, and to this the phenomenon is partly attributable. Those salts that have the least water of crystallization, decrepitate most powerfully. *Decrepitation* under the blowpipe is a characteristic of several minerals.

DEFLAGRATION. *Chem.* The rapid and scintillating combustion of certain substances, either alone or in mixture. The term is from *deflagro*, to burn, and applies particularly to the ignition of nitre with other bodies, in order that they may be oxidized by the disengaged oxygen. The substances previously mixed, are projected upon a red-hot surface, or mixed and gradually heated. Sulphurets and arseniurets, and carbonaceous matters are often deflagrated to determine their sulphur, arsenic, or carbon analytically. If deflagration be violent, carbonate of soda, common salt, &c., may be added to the mixture to diminish it.

DELIQUESCENCE. *Chem.* A term applied to those bodies whose affinity for water is such that they attract it from the atmosphere. Salts becoming moist in this way are said to be *deliquescent*, and the term may be considered as expressing the aqueous solubility of a substance. The derivation of the word is from *deliquesco* (*Lat.*), to melt down, because deliquescent bodies are apt to run into liquidity, as pearlash, chloride of calcium, &c.

DELPHIN. *Phar. and Chem.* Syn. Delphinea. A white, semi-crystalline, non-volatile alkaloid ($C_{27}H_{19}NO_2$?), extracted by sulphuric acid, from the seeds of the *Stavesacre* (*Delphinium Staphysagria*), in combination with an acrid, resinous matter, *Staphysain* ($C_{32}H_{23}NO_4$), which latter is insoluble in water and ether, but dissolves in dilute acids without neutralizing them.

Delphin melts at 250° , and dissolves in ether and alcohol, but not in water, and with the acids forms salts which, except the oxalate, are mostly gummy or deliquescent. Chlorine, at the ordinary temperature, is without effect upon it, but at 302° it colors it first green, and

then a deep brown, hydrochloric acid being simultaneously generated. Sulphuric acid reddens and carbonizes it.

DELPHINIC ACID. See **PHOCENIC ACID**.

DELPHINITE. See **EPIDOTE**.

DENSITY. *Phys.* A term expressing the quantity of matter or mass of a body in proportion to its bulk; or, in other words, the volume of matter comprised in a determinate space. Thus, when bodies, of uniform bulk, vary in density, their mass must be unequal. The density of bodies is in contradistinction to their rarity, and is inversely as their volume, and identical with specific gravity.

DEPHLEGMATION. *Chem.* An obsolete term, synonymous with *Concentration*, used by the alchemists to express the separation of "phlegm," an hypothetic principle of liquors, by evaporation. Hence pure and strong spirits are frequently said to be *dephlegmated*.

DEPHLOGISTICATED. *Chem.* From *φωτίζω*, to burn, and *νε*, down. A term applied by chemists of the 18th century to such bodies as had been burned, and thus deprived of their *phlogiston*, Stahl's hypothetic principle of fire. Oxygen was hence termed *Dephlogisticated air*, and chlorine *Dephlogisticated marine acid*.

DESICCATION. See **DRYING**.

DETONATION. *Chem.* When the ignition of bodies is attended with flame and noise, it is termed *Detonation*, and the phenomena are due to the sudden evolution of one or more elastic bodies, from a solid (gunpowder) liquid (per chloric ether) or gas (chloric oxide). These, and similar compounds, whilst assuming a greatly enlarged volume, corresponding with their elasticity, *répél* or compress the air and other bodies with a force productive of sudden noise and explosion. See *Fulminic Acid*, under **CYANOGEN** and **GUN COTTON**.

DETONATING POWDERS. *Chem.* Mixtures of certain combustible materials, the elimination of whose gaseous constituents, upon ignition, is so rapid and propulsive as to cause an explosion or detonation. **GUN POWDER** is the most common mixture of this class. The explosive compounds of the metals, silver, mercury, and gold, owe their fulminating power to a peculiar acid, the *Fulminic*, which is definitely united with their respective oxides.

DEUTOXIDE. *Chem.* A chemical term, improperly applied to the second degree of oxidation of any body possessing a variable range of affinity for oxygen. It is often applied to those compounds whose proportional equivalents of oxygen to the base is in the next combining ratio to that of protoxide. Thus, deutoxide of iron (Fe_2O_3) and protoxide of iron (FeO), because there is a rateable difference between them of a half atom of oxygen. The more correct expression in this case is *Sesquioxide of Iron*.

DEW. *Meteor.* The deposition of watery particles upon the earth's surface during the night, in certain seasons of the year, is solely dependent on the loss of heat which it sustains by radiation, and is based upon that general law of heat by which bodies tend to an equilibrium of temperature. The **ATMOSPHERE** is al-

ways more or less charged with watery vapor, which, being condensed by the cooler earth, with which it is in contact, appears on it in the form of dew. In damp, murky nights no dew is formed, because the clouds are an obstruction to the diffusion of the radiated heat, and consequently to the cooling of the earth. In spring and fall, when the greatest difference in the temperature of the nights and days exist, the formation of dew is most abundant. When the cooling of the earth's surface descends below 32° , the dew appears as *frost*.

DEW-POINT. *Meteor.* The degree indicated by the thermometer as the temperature at which dews commence to be formed. Its fluctuation apparently varies with temperature.

DEXTRIN. *Chem.* A gum-like product of the action of dilute acid upon starch, at 200° to 212° , and of **DIASTASE** upon a solution of starch, at 150° . From the latter it is precipitated by alcohol in a white, gelatinous mass, which becomes pulverulent after repeated ablutions with alcohol. The continued action of either of the above reagents converts it into grape-sugar, and renders it fermentable. With cold water it forms a mucilaginous solution, which, unlike that of fecula, is colored purple by iodine, and again, under certain circumstances, not at all affected by that body. From this circumstance, Jacquelin has shown that there are two distinct dextrins, the one of which, prepared by heating 1 part of starch granules with 5 parts of water for 45 minutes, at 320° , is tinted purple by iodine, whilst the same mixture, by a continued heating of one hour additional, is no longer colored by that body. The varieties of dextrin are also developed in the succession of changes induced by the action of acids upon fecula, and hence the fact is established that there is a dextrin *colorable* by iodine, and a dextrin *not colorable* by iodine. It derives its name from its property of polarizing light to the right. The formula of dextrin proper, according to Payen, is $\text{C}_{12}\text{H}_{10}\text{O}_{10}$, and its two combinations with oxide of lead ($\text{C}_{12}\text{H}_9\text{O}_9 + \text{PbO}$ and $\text{C}_{12}\text{H}_9\text{O}_9 + 2\text{PbO}$), dried at 356° , shows that whether free or combined, it is identical in composition with amylin. When dried at low temperatures, both of the above dextrinates of lead retain 1 eq. of water. (*Graham*.) Dextrin is distinguished from arabin, by giving no precipitate with basic acetate of lead, and by not forming mucic acid by the action of nitric acid.

A solution of dextrin, prepared by malt or diastase, imparts to beer a mucilaginous property.

Leicome, a variety of dextrin, is prepared by moistening 400 pts. starch with 1 pt. nitric acid, in 15 to 20 pts. water, drying in the air, and heating carefully to 302° .

British Gum, or roasted dry starch, is probably of the same composition as dextrin.

DI. *Chem.* A prefix applied, by some chemists, to suboxides or subsalts, as *dinoxide* of lead and *dichromate* of lead, (2PbO , CrO_3).

DIADOCHITE. *Min.* A brown mineral, from Arnshach, in Thuringen; yields acidulated water in a closed tube; colors flame

green, swells, and fuses on the corners to a black magnetic frit; gives the reaction of iron; boiling water extracts sulphuric acid. Form. $(3 \text{Fe}_2\text{O}_3, 2 \text{PO}_5, 12 \text{HO}) + 2 (\text{Fe}_2\text{O}_3, 2 \text{SO}_3, 12 \text{HO})$. See IRON SINTER.

DIABETIC SUGAR. See *Grape Sugar*.

DIALLAGES. See *ARGITE*.

DIAMOND. *Min. Tech. Syn.* Adamant, Brilliant. *Descrip.* Cryst. system, Regular. Occurs with most of the simple holohedral forms combined, and sometimes as the $\frac{1}{2} 6 \times 8$ -hedron. Its faces are often rounded by a tendency to combination. Cleaves brilliantly parallel to 8-hedron. $H. = 10$. $G. = 3.5$. Colorless, sometimes variously tinted; lustre brilliant, adamantine; transparent, translucent, if dark colored; possesses the highest degree of refraction, and often emits light in the dark after exposure to sunshine; fracture conchoidal; electric by friction.

Chem. Rel. Insoluble in acids; burns to carbonic acid by the hydroxygen blowpipe, leaving from 0.05 to 0.2 pr. ct. ashes, of a yellowish or reddish yellow color, containing silica and oxide of iron; it may also be consumed on platinum foil by the mouth-blowpipe or in powder by a spirit lamp.

Origin. Its origin is an interesting question, but not yet satisfactorily determined. Where found in rock, it appears to be a conglomerate, that in India consisting of rounded siliceous pebbles, cemented by ferruginous clay; at Minas Geraes, Brazil, in a talcose conglomerate similarly cemented. The greater part are washed out of loose alluvial deposits. Petzholdt observed a cellular structure in some diamond ashes, and a similar structure in a brown enclosure in a diamond. Sir D. Brewster infers from its relations to light, locality, &c., that it is of vegetable origin. Wöhler examined 50 diamonds, containing enclosures, without observing anything indicating a vegetable structure.

Local. and Value. In India, between Gollconda and Masulipatam; near Parma, in Bundelkund; on the Mahanuddy, near Ellore; Pontiana, on Borneo. In Brazil, in the province Minas Geraes. In Russia, on the Ural Mtns. In U. S., in N. Carolina? The largest one known, in possession of the Great Mogul, is said to have weighed 900 carats. The Russian specimen, from India, weighs 193 carats. The French (Pitt or Regent diamond) weighs $136\frac{1}{4}$ car., is very pure, cut as a brilliant, and is estimated at £125,000. The Austrian weighs $139\frac{1}{2}$ car. The Rajah of Mattan has one weighing 367 car., from Borneo. The carat = 3.174 grs. Troy. The value of diamonds is estimated from the weight in carats, by multiplying the square of that weight by the estimated value of one carat. Thus, if a good, clear diamond, in the rough state, but without flaws, weigh one carat, it is worth £2, if 3 carats, $3^2 \times 2 = £18$. If it be cut into a well-shaped brilliant, the square of the weight should be multiplied by £8, the value of one carat; thus, a perfect brilliant of 4 carats is valued at $4^2 \times 8 = £128$. It follows of course that the multiplier diminishes with the quality of the brilliant.

Use. The diamond is cut chiefly into 3

forms, the brilliant, the rose, and the table, by means of its own dust; and if a large piece is to be cut off, it is done by a steel wire stretched on a bow, and anointed with the dust. Advantage is sometimes taken of cleavage to affect the same, but the operation requires great firmness and dexterity. In setting the glazier's diamond, the point is acute-angled, and the curved sides of the angle assist in wedging the glass asunder. Small splinters or sparks are also set for marking glass.

Supply. It is difficult to ascertain the total amount of diamond supplied to commerce. It would seem that the supply has diminished in Brazil, for von Eschwege estimates the average annual supply from 1730 to 1814, at 36,000 carats, while from 1800 to 1806, it was 19,000 carats pr. an. It is observed that the same cubic mass of diamond-bed will yield, on washing, about the same number of carats, whether larger or smaller.

DIASPORE. *Min.* Cryst. Right Rhombic, with perfect cleavage. $H. = 6$. $G. = 3.3 - 3.4$. Colorless, also reddish, bluish, brownish; lustre vitreous, splendid on cleavage planes; translucent. Decrepitates in a tube, giving little water at a low heat, much more by ignition, infusible, soluble in fluxes, giving a manganese reaction with soda on platinum; colored deeply blue by cobalt solution. Form. $\text{Al}_2\text{O}_3, \text{HO}$. It occurs at Schemnitz and Ekatherinenburg.

DIASTASE. *Chem.* Prepared by moistening bruised malt with half its weight of water, expressing and straining the liquid, adding a little alcohol to destroy its viscosity, filtering, and adding more alcohol to precipitate diastase. It is redissolved in water, reprecipitated by alcohol, and dried at 100° to 120° . Malt yields $\frac{1}{2}$ of 1 pr. ct. diastase. It is white, amorphous, inodorous, tasteless, neutral, not precipitated by subacetate of lead, without action on sugar, gum, inulin, &c., its most striking property being its action on starch solution, changing it into dextrin, and then into starch-sugar. 1 pt. of diastase will thus metamorphose 2000 pts. of starch. It acts at 32° , but most powerfully at 140° to 150° . Its solution readily acidifies and loses its power; boiling decomposes it instantly. It contains nitrogen, and is allied to gluten or albumen, but its exact composition is unknown. It exists near the germ of malt and the eye of the potato, in the pancreatic juice and saliva, and is probably the same with the gasterase of Payen.

DICHOITE. See *CORDIERITE*.

DIDYMIUM. *Chem.* (From *δίδυμοι*, twins). A metal accompanying cerium and lanthanum. Its presence was the cause of the brown, red, and yellow colors, often observed in the compounds of cerium and lanthanum, from which Mosander succeeded in separating it, but as yet the separation is imperfect. L. Bonaparte recommends a concentrated aqueous solution of valeric acid to precipitate pure valerate of cerium, while the solution contains didymium with a portion of cerium. Mosander separated the sulphates of the other two metals from that of cerium by repeated

DIFFERENTIAL THERMOMETER.

crystallization. The dry sulphates of the two metals are dissolved portion-wise in 6 pts. water, cooled to 48°, then heated to 104°, when the sulphate of lanthanum precipitates, with a little didymium-salt; thus treated for 10 or 12 times, the salt of lanthanum is obtained pure. The solution is next evaporated slowly to $\frac{1}{4}$ of its bulk and poured off from the saline mass, consisting of larger red crystals and small prisms. Boiling water is poured over, and immediately poured off, the larger crystals redissolved and similarly treated, finally leave the red crystals of pure sulphate of didymium.

Potassa throws down from the sulphate the *hydrated oxide of didymium*, of bluish violet color, which by absorption of carbonic acid during washing becomes more reddish. The oxide, obtained by igniting the hydrate or carbonate, is a darker or lighter brown, and at a white heat it becomes grayish white, with a greenish tint. Before the blowpipe it dissolves in mic. salt in the outer flame with the same amethystine color as titanium in the inner flame. Its salts are amethyst-red, with a marked bluish tint.

The *sulphate* forms red triclinic crystals, soluble in 5 pts. water, at about 60°, but at the boiling point it requires 50.5 pts. water for solution. It bears gentle ignition without decomposition, and loses $\frac{2}{3}$ of its acid by a white heat. It forms an amethyst-red double salt with sulphate of potassa, insoluble in a saturated solution of sulphate of potassa. The *nitrate* is deliquescent and difficult to crystallize.

DIFFERENTIAL THERMOMETER. See THERMOMETER.

DIFFLUANE. See URIC ACID.

DIFFUSION. *Chem. Phys.* A term given to the peculiar phenomena observed by the mixing of gases. Priestley observed that when gases were conducted through heated porous earthenware tubes, they escaped into the fire, and the fire-gases penetrated the tubes. Dalton investigated this mutual penetration of gases, by inverting one bottle over another, each filled with a different gas, and connecting them by a small tube thrust through corks in their openings. He found that they mingled together, and even contrary to their specific gravities; thus if the upper were filled with hydrogen, and the lower with carbonic acid; they were found, after a short time, mingled uniformly together in the two bottles. He hence inferred that one gas expands into the space occupied by another, as though into a vacuum, or at least that the resistance of one gas to another is imperfect. Graham, who has investigated this subject most fully, found that equal volumes of different gases escape through capillary orifices in different times, which bear some relation to their specific gravities. He found that the gaseous volumes which escaped into the air after the diffusion was complete, were inversely as the square root of their densities, or very nearly so. This volume, which he terms the diffusion-volume, $= \sqrt{\frac{T}{d}}$, in which d = the density of the gas. The following table shows the approximation of observation

DIGESTER.

to calculation from the formula, air being assumed = 1.

Gas.	Calculated.	Observed.
Hydrogen.....	3.795	3.830
Olefiant gas	1.014	1.019
Nitrogen	1.014	1.014
Carbonic acid	0.809	0.812
Sulphurous acid	0.671	0.680

Hence lighter gases have a greater diffusion-volume than those heavier than air. Where two gases are mingled together, the more diffusive escaped much more rapidly than the less diffusive gas. Thus, if, as in Dalton's apparatus, the upper flask contain equal volumes of hydrogen and olefiant gases, and the lower flask, 7 times as capacious, be filled with carbonic acid, after 10 hours, the upper flask, besides carbonic acid, contains 4 times the volume of olefiant gas as of hydrogen. *Graham.*

Besides a capillary tube, various porous substances may be employed in experiments on diffusion, such as a cast plate of gypsum, charcoal, cork, thin caoutchouc, bladder, &c., but then the experiments are more or less influenced by the fineness of the pores, by the difference of adhesion and of chemical attraction between the gases and the diaphragm. A thin caoutchouc sheet, piece of bladder, or gold beater's skin, tied over the wide neck of a bottle, filled with hydrogen and exposed to the air, is pressed inward and may burst. Gases, most easily liquified by cold, pressure, or absorption by water, pass most easily through membrane, caoutchouc, &c. Thus the time required by equal volumes of gases to pass through the same membrane was

1 minute with ammonia.
2½ minutes with sulphuretted hydrogen.
5½ " carbonic acid.
28 " olefiant gas.
37½ " hydrogen.
113 " oxygen.
160 " carbonic oxide. <i>Mitchell.</i>

Vapors rise into the air in a similar manner, and seem to follow the same laws of diffusion as the permanent gases.

DIGENITE. *Min.* An amorphous copper-ore, from Chili and Sangershausen, in Thuringen. H. = 2.5 — 3. G. = 4.57 — 4.68. Dark lead-gray, with metallic lustre and black streak. Form. Cu_2S , 3 CuS , with 71 pr. ct. copper.

DIGESTER. *Chem. and Tech.* A strong, steam-tight metallic vessel, fitted with a safety-valve, and used for the solution of those bodies which do not yield to the solvent power of liquids except at high temperatures. It is a contrivance of Papin, in which he subjected bones to the action of highly heated water, in order to render their gelatinous constituent more digestible and palatable. Its efficiency in this respect is founded upon the fact that the boiling temperature of fluids is raised in a certain proportion to the pressure. When this vessel, to which the French *autoclaves* are similar, is heated, the steam generated and filling the unoccupied space within, exerts a pressure upon the surface of the liquid beneath, and by thus preventing further ebulli-

tion, causes, to a certain extent, an accumulation of heat therein. In the instance of water, the expansive power of the vapor of which, at 212° , is sufficiently strong to overcome the atmospheric pressure, it can be heated highly in this vessel without ebullition and evaporation, the highest limit being the strength of the material.

DIGESTION. *Physiol.* The transformation of food in the bodies of animals into new combinations designed to reproduce those parts of the body which have been wasted by excretions. There is a remarkable similarity in some respects between digestion and the ordinary operations of the laboratory. The food is pulverized or masticated, and moistened at the same time; it is digested in a powerful solvent in the stomach, precipitated, filtered, &c. The theory of the operation is by no means clear. Pepsin was supposed to exert a powerful influence in dissolving, then free muriatic acid and pepsin, and more lately it has been supposed that muriatic acid is combined, and that lactic acid is free. Although the subject is of the highest importance in its physiological bearings, yet its present varying state excludes a more elaborate notice in a practical work like the present.

DIGESTION. *Chem. Tech.* It consists in exposing a body to the action of a liquid for some time, at a temperature of from about 90° to its boiling point. It calls in the assistance of the element *time* for effecting certain compositions or decompositions, the effects of higher heat in a short time being often different, independent of vaporization, at the boiling point. Digestion is often performed in a flask, which may be closed, or nearly so, but if in an open vessel, as in the bell-shaped glass, fig. 10, p. 22 (ANALYSIS), then it should be covered by a watch-glass, or capsule, like fig. 11, so that the vapor condensing on the bottom of the cover may fall back again into the glass.

DIGESTIVE SALT. The old pharmaceutical name of chloride of potassium.

DIGITALIN. *Chem.* A colorless, semi-crystalline, neutral substance, extracted from the *Purpurea digitalis*.

Prep. To the alcoholic tincture of the leaves, evaporated to syrupy consistence, add 1 part acetic acid and 3 parts of water; agitate the solution with animal charcoal, neutralize with ammonia, and precipitate the digitalin with tannic acid. The precipitate is treated with oxide of lead and digested with alcohol. The solution, decolorized by animal charcoal, yields, on evaporation, a residue, from which ether removes some foreign matters, leaving the pure digitalin undissolved. *Henry.*

Prop. It dissolves in alcohol, and is precipitated from its solution in acid by the addition of water. Concentrated sulphuric acid gives it a red color, which ultimately becomes olive-green. Its intense bitterness is partially modified by heat. Homolle announces the presence in fox-glove of another substance, which crystallizes in white needles, and is insoluble in water and alcohol, but as yet it has not been obtained in sufficient quantity for a critical examination.

Digitalic Acid. It is in needle-shaped crystals, and forms salts with the bases, of which those that are soluble readily become yellow in the air. *Chem. Gaz.*, vol. iii. p. 232.

DILITURIC ACID. See URIC ACID.

DIMORPHISM. *Ger. Fr.* Dimorphie (*Ja, twofold, μερφ, form.*) It is stated under CRYSTALLIZATION that the same body is always crystallized in forms referrible to one of the six classes or systems. There are, however, a few bodies, elementary and compound, which seem to have the power of assuming the forms of 2, and possibly of 3, different systems; or, if referrible to only one system, of presenting forms, the radicals of which have a different measurement of angles. But besides this difference in form, there is also a difference in spec. grav., or hardness, or color, or other external properties. The following table exhibits most of these bodies, with their name, formula, crystal-system.

Dimorphic Substances.	Formula.	Cryst. Syst.
1. Carbon	C	{ 1 Diamond. 6 Graphite.
2. Copper	Cu	{ 1 Native. 6 Native, and by fusion.
3. Protoxide of copper	Cu ₂ O.....	{ 1 Red copper ore. 6 Fibrous red copper.
4. Subsulphuret of copper	Cu ₂ S.....	{ 1 Vitreous copper. 3 By fusion.
5. Bisulphuret of iron.....	FeS ₂	{ 1 Iron pyrites. 3 Spear pyrites.
6. Arsenious acid.....	AsO ₃	{ 1 Native and sublimed. 3 Glassy.
7. Oxide of antimony	SbO ₃	{ 1 Sublimed. 3 Native.
8. Carbonate of lime.....	CaO, CO ₂	{ 3 Arragonite. 6 Calc. spar.
9. Carbonate of iron	FeO, CO ₂	{ 3 Junckerite. 6 Sparry iron.
10. Nitrate of potassa.....	KO, NO ₅	{ 3 Common form. 6 From small quantities.
11. Sulphate of potassa	KO, SO ₃	{ 3 Common form. 6 In refining kelp.

12. Sulphur.....	S.....	3 Native, and from solution.
		4 By fusion.
13. Bisulphate of potassa	KO, 2 SO ₃ , HO	3 From solution.
		4 By fusion.
14. Selenate of zinc	ZnO, SeO ₃ , 7 HO...	3 At low temperature.
		4 At higher " "
15. Sulphate of zinc.....	ZnO, SO ₃ , 7 HO....	3 Below 126°.
		4 Above " "
16. Sulphate of magnesia	MgO, SO ₃ , 7 HO ...	3 Below " "
		4 Above " "
17. Sulphate of nickel.....	NiO, SO ₃ , 7 HO....	3 Below 59°.
		2 Between 59° and 68°.
		4 Above 86°.
18. Chloride of mercury.....	HgCl.....	3 From solution.
		3 By sublimation.
19. Titanic acid.....	TiO ₂	2 Anatase.
		2 Rutile.
20. Iodide of mercury.....	HgI	2 From solution, red.
		4 By heat, yellow.
21. Garnet.....	} See these for form-	1
Vesuvian		2

It has been remarked that the second form of (2) protoxide of copper, observed by Häuy and Seebeck, was a twinned form of the first system. It will be observed from the above table, that sulphur, several isomorphous sulphates, and the bisulphate of potassa, are all found in the two systems 3 and 4, but the sulphate of nickel is trimorphic. It is possible that carbonate of lime may be trimorphic, for barytocalcite belongs to the 4th system. Arsenious acid and oxide of antimony replacing each other in native or artificial states in each of the systems 1 and 3, they are isodimorphic. The carbonates of lime and iron are also isodimorphic. Titanic acid crystallizes in two forms of system 2, but their radical 8-hedra have different measurements.

The spec. grav. of calc. spar is 2.721, that of arragonite 2.931; the spec. grav. of anatase is 3.826, that of rutile 4.249. The external characters of the diamond and graphite are very striking in spec. grav., color, hardness, &c. The two forms of arsenious acid are differently soluble.

Vain attempts have been made to refer dimorphism to a more general law. To say that a difference of temperature or other circumstances determine two or more forms of the same body, is no explanation. It was formerly supposed that the presence of strontia in carbonate of lime always determined the form of arragonite, in preference to that of calc. spar, and that hence a foreign substance was the main cause of dimorphism, but the twofold form of pure sulphur refutes this theory, independently of the fact that arragonite has been found consisting of pure carbonate of lime. It is probable the presence of a foreign body in the crystallizing liquor may often determine the crystal-system of a dimorphic body, whether it crystallize with the principal substance or not; thus the presence of carbonate of strontia, which only assumes the right-rhombic form, may determine carbonate of lime to crystallize as arragonite. But, in most of those cases investigated, the prevailing condition of difference in form is due to difference of temperature. A solution of bi-carbonate of lime, crystallizing at common

temperatures, forms calc. spar crystals; by evaporation in a water-bath, there is a mixture of calc. spar and arragonite; by adding a boiling solution of muriate of lime to carbonate of ammonia, arragonite precipitates. Fused carbonate of lime has the form of calc. spar, and a crystal of arragonite falls to calc. spar crystallites by a low ignition. Hence, at about 212°, arragonite is formed, but much above or below 212°, calcareous spar. It is supposed that the particles of dimorphic bodies arrange themselves in two ways to form the 2 classes of crystals, or that the atoms of one are multiples of those of the other. See ISOMERISM, AMORPHOUS, CRYSTALLIZATION.

DIOPSIDE. See AUGITE.

DIOPTASE. *Min.* Syn. Achirite, Emerald Copper, Smaragdo-Chalcite. It occurs in the Kirgheses Steppes of Siberia. Cryst. Hexagonal, cleaving parallel to an obtuse rhomb. H. = 5. G. = 3.278. Color emerald-green, darker and lighter; lustre vitreous; transparent, subtranslucent; brittle, with uneven conchoidal fracture.

Yields water in a tube, and becomes black; on coal, becomes black in the outer and red in the inner flame, tinging the flame green; gives the reaction of copper in borax and mic. salt, leaving a silicious skeleton in the latter; reduces partially to metal in borax, and wholly with much soda. Soluble in nitric acid, gelatinizing; decomposed by ammonia, caustic, and carbonated. Form. 3 CuO, 2 SiO₃ + 3 HO.

DIORITE. *Geol.* Syn. Greenstone, Trap. A dark-colored, igneous rock, consisting of albite and hornblende, sometimes crystalline, sometimes compact.

DIOXYLITE. *Min.* Syn. Lanarkite, Sulphatocarbonate of lead. Cryst. Oblique Rhombic, laminae flexible. H. = 2 — 2.5. G. = 6.8 — 7. Greenish white, pale-yellow, gray; lustre adamantine, pearly on cleavage-planes; transparent, translucent. Fusible on coal to a white bead, containing reduced lead; partially soluble in nitric acid with effervescence. Form. PbO, SO₃ + PbO, CO₂. It occurs at Leadhills.

DIPLOITE. See LATROBITE.

DIPPEL'S ANIMAL OIL. *Chem. Tech.*
2 x 2 521

DIPYRE.

Syn. Empyreumatic Oil, Rectified Oil of Hartshorn. The fœtid, volatile oil, produced by the destructive distillation of bones, and obtained as a secondary product in the manufacture of bone-black. It consists of four oily, salifiable bases, *odorin, animin, olamin, and ammolin (Unverdorben)*, and contains creasote. (*Reichenbach.*) In its natural state it is brown and viscid, but can be rendered colorless by redistillation, the action of the air and light, however, soon altering it again. Carbon, hydrogen, oxygen, and nitrogen are its ultimate constituents, the last, doubtless, being chiefly due to the presence of ammonia, which also gives it an alkaline reaction.

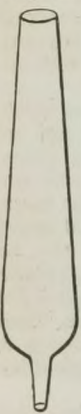
DIPYRE. See **SCAPOLITE**.

DISINFECTING LIQUOR. See **Salts of Sodium.**

DISACRYL. *Chem.* The white powder ($C_{10}H_7O_4$) insoluble in acids and alkalis, which is formed when **ACROLEIN** is left in contact with water. *Disacrylic resin* ($C_{20}H_{13}O_6$), a white pulverulent substance, soluble in alcohol, ether, and alkalis, and insoluble in water, is sometimes formed under precisely the same circumstances as *disacryl*. It fuses at 212° , and separates from its evaporated alcoholic solution in brittle, glittering scales. *Red.enbacher.*

DISPLACEMENT. An economical mode of extracting the soluble matter of vegetable and other substances. The process consists in the percolation of menstruum through a certain bulk of the material to be acted upon. That portion of the liquid which first passes through, as soon as it becomes surcharged, is displaced by another following it, and so on the action is continued, until the absence of color and taste in the liquid running through indicates a perfect exhaustion of the material. The form of the apparatus is such as to do

Fig. 40.



away with the necessity of filtering, and, independent of a saving of time, there is less loss of menstruum than by the old methods of extracting the soluble matter of substances. For making expensive tinctures, &c., on a limited scale, the apparatus should be of glass, and of the form represented by fig. 40.

The greater diameter at the bottom of the bulb admits of the reception of a large portion of material, while the gradual converging of the barrel upwards, gives a sufficiency of column pressure. An economical substitute is the neck of a retort or a glass tube. To prevent the passage of small particles of stuff with the surcharged liquid, the barrel should be plugged at its outlet with a small ball of raw cotton.

For larger operations, the percolator should be of tinned copper, or tin, and of form as shown by fig. 41.

In chemical laboratories, where all the operations must necessarily be on the most extended and economical scale, a different arrangement is followed. For convenience the column is detached, so that it can be removed and replaced at pleasure.

DISPLACEMENT.

Fig. 41.

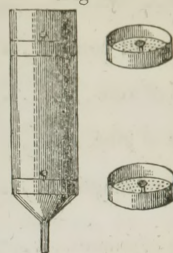
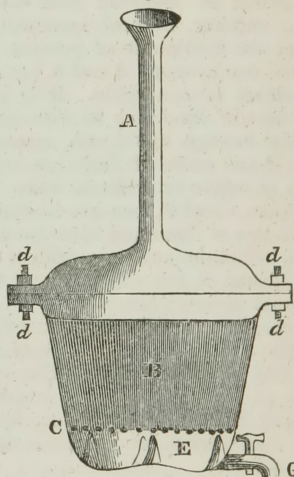


Figure 42 exhibits the whole apparatus; A is the column, B the reception cylinder, in the interior of which, about 8 inches from the bottom, is fixed the cullendered diaphragm C. On this diaphragm, covered with a coarse cloth, rests the bark or other substance to be exhausted, and as soon as the machine is charged therewith, the column, held asunder by pulleys, is let down and fastened closely by means of the bolts *d d*; the joints being rendered water-tight with lead and felt washers. Ascending to the top of the

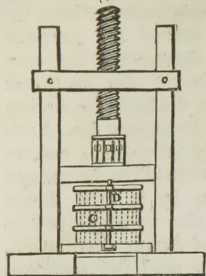
Fig. 42.



column, the menstruum is then poured in and replaced as fast as its level diminishes. The liquid in filtrating through, as soon as it is surcharged and reaches the diaphragm, is pressed into the reservoir E, from whence it is drawn off through the cock G. By this arrangement, no more liquid need be used than is sufficient, for as soon as the exhaustion is complete, it runs through colorless and tasteless, and thus indicates that the operation is finished. Alcohol and pure or acidulated waters are each equally applicable to this arrangement. The pressure of one atmosphere being about 15 lb. upon every square inch of surface, without reference to the diameter of the tube conveying the pressure, a small quantity of liquid in the tube, A, is sufficient to give a large aggregate of pressure on the liquid in B, the amount of which pressure may be increased at pleasure by increasing the height of the tube A. The cylinder should be cased exteriorly with wood so as to enable its material to resist the pressure applied. When the material is exhausted, it must be taken out, thrown into a cullendered

cylinder, and freed of all its liquid contents by

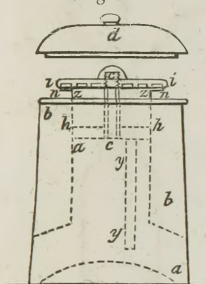
Fig. 43.



pressure. The apparatus is represented by fig. 43. When the cake is hard, and will yield no more to pressure, the cylinder, which is of elastic sheet-iron, and fastened together, in part by a broach, D, and behind with hinges, is opened by withdrawing the broach and its contents emptied out. Reset again, it is ready to receive new quantities. This cylinder is separate from the press, and, when to be subjected to its action, is placed immediately upon the bed, which should be of tray form, to carry off the liquid oozing out.

Another form of a displacer is that represented by fig. 44. It resembles the French coffee biggen, and consists of two principal capacities, *aa* and *bb*. *a* is the boiler or caldron; *b* the reservoir to contain the extract. *z*, the box for the reception of the material to be acted on, is a cylinder with two perforated plates, *hh* and *nn*, the holes in *nn* being very small.

Fig. 44.



This plate serves as the filter, and the openings in *hh* being merely for the passage of extract, are not necessarily so fine. Upon the plate *nn* is surmounted another thick plate, *ii*, similarly pierced with holes throughout its entire superficies;—it is fastened upon the tube, *cc*, by the female screw, *cc*, cut through its centre, thus closing the tube and retaining the material in the box, *zz*. The whole is shut in by a top or cover, *d*.

To charge the caldron, *a*, pour the liquid to be used into the box, *z*: thence it passes through the tube into the vessel, *a*. Then fill the box, *z*, with the material to be extracted, screw the plates, *nn* and *ii*, in their respective positions, place on the cover, and apply heat, by lamp or otherwise.

So soon as the liquid begins to boil, the elastic force of the vapor produced within the caldron, *aa*, forces the liquid to mount through the tube, *yy*, across the plate and material contained in the box, *hh*, then to filtrate through the plate, *nn*, and finally to pass (charged with extractive matter) through the openings of the plate, *ii*, into the reservoir, *bb*, whence it is drawn off for use.

DISTHENE. See **KYANITE**.

DISTILLATION. *Lat.* Destillare, to drop down. A process for separating a volatile liquid from a solid or less volatile liquid, by heating the mixed substances and collecting the condensed vapor. If the vapor collect as a solid, the process is termed *sublimation*, as in the preparation of flowers of sulphur. If the body obtained did not exist as such, but is the result of metamorphosis by heat, the process is termed *dry* or *destructive distillation*. The

liquid passing over is called the *distillate*, and the residue was formerly termed *phlegm*, if liquid, or *caput mortuum*, if solid. Chemists also distinguished formerly three kinds of distillation, by ascent, lateral, and by descent, of which the 2 former are now unitedly termed *distillation*, and the last *eliquation*. *Rectification* is the redistillation of the same liquid alone; *Cohobation*, the distillation of the same liquid several times from the same residue. The origin of this important process is unknown, the first distinct notices of it being by Arabian writers, who may have derived it from the East, with many other arts. It improved a little in the hands of the alchemists, but the most important improvements date within a half century.

The apparatus in which distillation is conducted is termed a *still*, if large; or a *retort*, if of small dimensions. The whole apparatus consists usually of four parts, which may be separate, or even be all in one or two. Thus, in a still, we have the *body*, or kettle, in which the liquid is boiled, the first refrigerator, or *helm*, in which the vapor condensing returns to the kettle, the 2d refrigerator, *worm* or condenser, in which distillate condensing flows into the *recipient*. In a glass retort, the lower part of the bulb is the kettle, the upper part the helm, the neck or beak is the worm, to which a glass balloon or other convenient recipient is attached.

Glass Retorts are frequently used in the laboratory, and sometimes in technical operations. They may be tubulated or not. The two prevailing forms, pear-shaped and globular, are represented in figs. 45 and 46, the former being

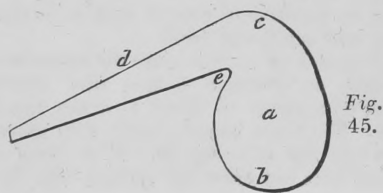


Fig. 45.

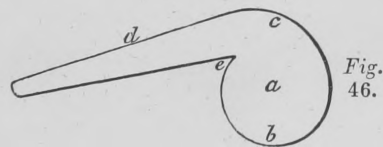


Fig. 46.

deeper in the bulb, from *a* to *b*, than the latter, causes more of the spirited liquid to flow back; the same result is also attained by commencing the downward slope of the neck, *d*, at *c*, or better directly over the sharp angle, *e*. The globular form has the advantage that, presenting a larger surface and less depth, from *a* to *b*, a liquid boils in it more quietly. In either case the bulb of the retort should be as thin as is consistent with strength.

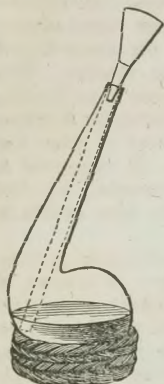
The stopple should be placed near the point, *c*, so that liquid collecting about it may flow back. In case a retort be not constructed with the highest point, *c*, nearly over *e*, the retort may be used by putting the neck in a

DISTILLATION.

more horizontal position, or it may even be placed with the neck inclined upwards.

A tubulated retort is easily filled by the use of a straight funnel-tube, or by an S tube, fig. 52, if it is to be added portionwise. A plain

Fig. 47.



retort is filled by a funnel-tube through the neck, or by a funnel and tube, as in fig. 47. By this method portions of the liquids to be distilled are prevented from flowing down the neck with the distillate.

A plain tubulure may in almost all cases be used, and closed by a cork. A glass stopple, being of thick glass, is less rapidly expanded than the tubulure, and sinks deeper in the tubulure when the latter expands, so that on cooling it is clasped so tightly as to

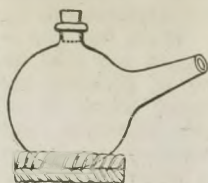
endanger the retort or to render it difficult of extraction. This inconvenience may be remedied by now and then loosening it, and taking it out when the distillation is complete.

Retorts are heated by being placed in a water or sand bath, fig. 52, placed over the naked fire, or they may be held by an upright or horizontal wooden clamp, lined with cork plates where it clasps the neck, or by a double zigzag of metal, in either of which cases it may be heated by a flame or live coals. It is less advisable to rest it on a triangle of thick wire, unless a sheet of wire gauze surround the bottom of the bulb. Where it is to be subjected to the heat of softening glass, the bulb may be previously coated with a mixture of clay and sand, and dried.

Recipients or receivers are the glass balloons, globes, or common bottles into which the beak of a retort is thrust to catch the distillate. They are usually made with more than one opening, as in fig. 48. If the beak of the retort does not enter far enough into the reci-

DISTILLATION.

Fig. 48.



ipient, an *adapter* (fig. 7, p. 46, and fig. 52) may be interposed, which also serves the purpose of increasing the distance of the recipient from the fire, of assisting condensation, &c. A second tubulure is convenient to allow the escape

of gass or expanded air, by a tube thrust through a cork, and may also be employed as a syphon to draw off liquid during distillation, see fig. 52, by ceasing to cool the recipient for a time, when the accumulation of vapor drives over a portion of the liquid. One neck of the recipient is sometimes drawn out into a tube, which enters a flask, as fig. 49, or a tube

Fig. 49.

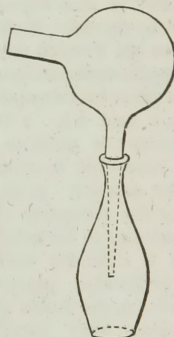
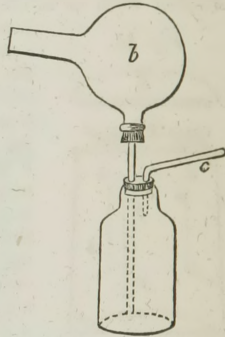


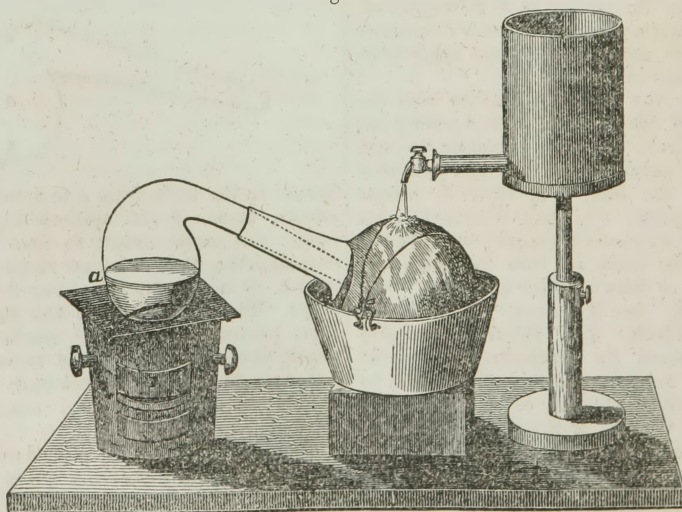
Fig. 50.



thrust through an inserted cork, and passed into the cork of a flask, fig. 50; the latter may have an exit tube, *c*.

With many liquids, the cooling influence of the air on the whole apparatus is insufficient to condense the distilling vapors, especially when the whole becomes heated by the vapors after the operation has continued for some time. Hence various expedients are resorted to in order to keep the receiver cool, such as by setting it in cold water, surrounding it by ice or snow. Fig. 51 exhibits the

Fig. 51.

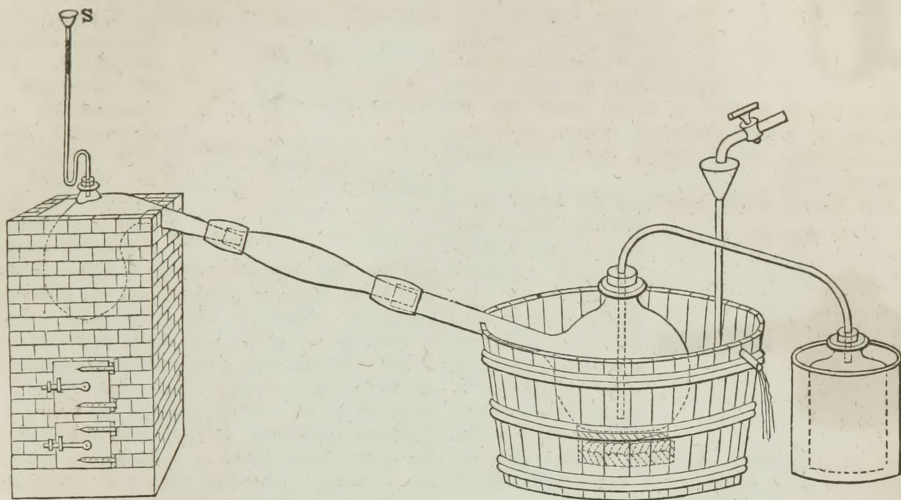


simplest forms of retort and recipient combined together, the latter being placed in a

vessel and surrounded with muslin, linen, tow, &c., on which a stream of water is suffered to

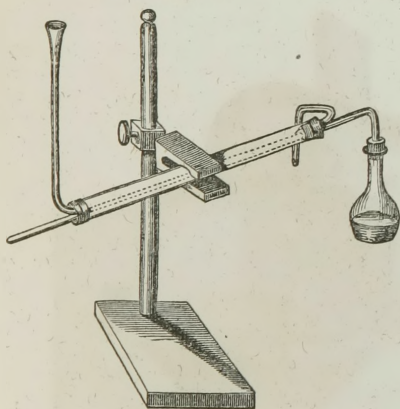
flow, the quantity being regulated by the stopcock of the reservoir. Fig. 52 exhibits a more complex combination of a tubulated retort with its S tube, an adapter, a recipient, placed in a vessel with a constant stream of cold water flowing into it, and a syphon-tube with a second receiver

Fig. 52.



The globular form of the recipient not offering a sufficient cooling surface to volatile liquids, various forms of *condensers* have been adopted to effect the condensation of the distillate. Fig. 53 represents a convenient condenser for small operations. It consists of a

Fig. 53.

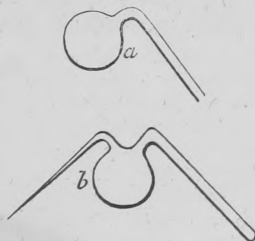


small tube running through a large one from the flask or retort. The large tube is closed at either end by a cork perforated with two holes, into which tubes are fitted as shown in the figure. A constant stream of cold water, entering through the long funnel-tube at the lower end, passes up between the inner and outer tube, flowing out through the short and bent upper tube. The same contrivance may be employed for larger operations, by constructing the apparatus of brass, iron, &c. Pl. II., figs. 8 and 9, represents it on a technical scale for the manufacture of pyroligneous acid. *gg* is the tube for conducting the vapors from the still, *a*, through the larger tubes, *i i*, the space between them being filled with flowing water, which descends from the reservoir, *k*, through

the tube, *l*, and upward through *o o*, when it discharges through *p*.

For microchemical distillations, bulbs are

Fig. 54.



blown on small tubes, as in fig. 54, by the table blow-pipe, which may be plain, as *a*, or tubulated, as *b*; the tube serving to draw up the liquid to be distilled, may be sealed in the flame. Small retorts of several cubic inches content may be made in this manner. Still simpler forms may be used, by closing a tube at one end and bending it, as in fig. 55; the

liquid to be distilled being at *a*, and the recipient at *b*. By pouring water into *b*, the retort is sealed from the air. If a gas is to be collected, the open end of the tube may be drawn out finely and bent downwards if necessary.

Fig. 55.



liquid to be distilled being at *a*, and the recipient at *b*. By pouring water into *b*, the retort is sealed from the air. If a gas is to be collected, the open end of the tube may be drawn out finely and bent downwards if necessary.

Clay Retorts. Earthenware retorts have nearly the form of fig. 46, usually without a stopple. The bulb, *a b*, is often made to slope gradually into the neck, *d*, dispensing with the sharp angle, *e*. Retorts of porcelain have either the form of fig. 45 or 46, with or without a stopple. Both are used chiefly in dry distillation, but are liable to fracture from too rapid heating or cooling.

Platinum Retorts, of a small size, are frequently useful in heating substances apart from the air, for preparing fluohydric acid, &c.

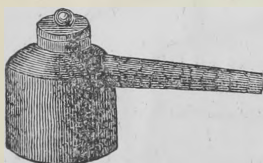
Fig. 56.



Fig. 56 represents a good form of these, the body of which, *a*, *d*, is made like a crucible, and may be used as such; it has a rim, *d*, of thick metal around it. The neck, *c*, may be soldered to the helm, *b*; or the two may be made from one piece; and the lower narrowing rim is ground to fit the inner side of the rim, *d*. Large platinum retorts, used for concentrating oil of vitriol, have the usual form of a still.

Iron Retorts, when employed for small operations, have the form of fig. 57, with the body cylindrical, as in the fig., or globular. A simpler form is that of a mercury flask, or short cylinder, with a gun-barrel screwed into the top and bent as required. An iron mortar may be employed as a receipt if necessary. Such retorts are best made of cast-iron.

Fig. 57.



For larger technical operations, retorts of cast-iron are frequently used. Pl. II., figs. 8 and 9, represents a square one of cast-iron, *a*, for the dry distillation of wood. The most common form is that of a cylinder or half cylinder, the former of which is shown in figs.

37—38, p. 437, for preparing muriatic acid, the brick stack enclosing 6 such retorts, *c*. The semicylindric form is mostly used for the dry distillation of coal in the preparation of illuminating Gas.

Small metallic retorts may also be made of sheet-tin or copper for distilling liquids, for sublimation, or for dry distillation.

Fig. 58.

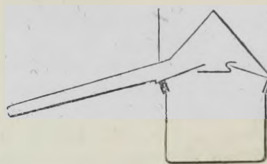
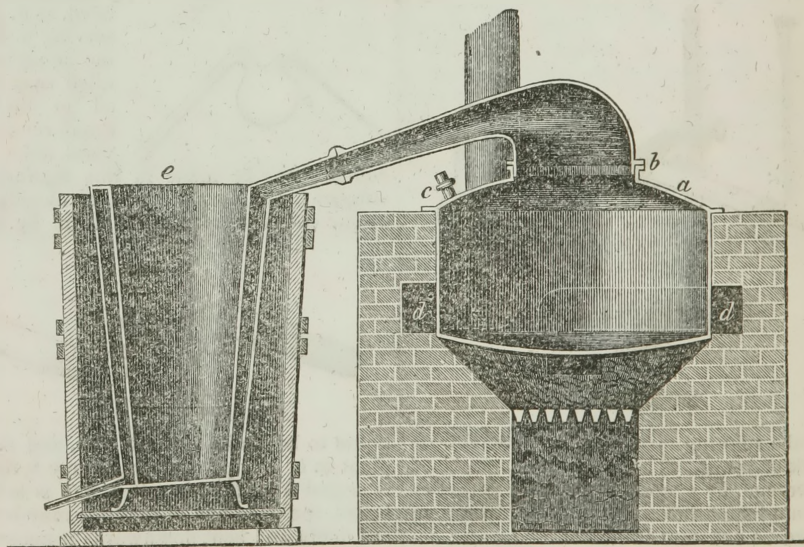


Fig. 58 represents an economical and convenient form. The whole may be soldered together. The body may be cylindrical or crucible-shaped, and the rim strengthened by a hoop of wire.

The helm consists of two cones, the inner and lower of which is truncated, and covered loosely on the under side by a movable disk of sheet-metal, with a crooked tongue clasp on the truncated edge. The neck, where it is soldered to the lowest point of the cone, is a flattened cylinder. A high rim, rising above the outer cone, forms a cylinder for holding ice or water, a constant stream of which may be allowed to flow on and off by tubes.

Stills. These are the larger retorts employed in the distillation of liquids, especially the alcoholic, and are mostly constructed of copper, tinned or not on the inner surface. A leaden still is well adapted to ether, &c. Fig. 59 represents a still set in brick-work, with its

Fig. 59.

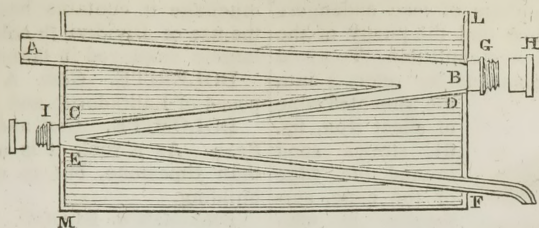


helm and condenser attached. It is set in such a manner that the fire heats both the bottom and the sides through the flue, *d*. The dimensions of the body or kettle, *a*, vary, a good proportion being the height to the diameter, as 2 to 5. Material may be added, during distillation, through the tubulure, *c*, and liquid drawn off by a tube passing from the bottom through the mason-work. The helm, made of tinned copper or solid tin, is fitted accurately into the mouth of the body at *b*; but it is

placed towards one side when the material to be distilled contains sediment that requires stirring, in which case the shaft of the stirring apparatus descends vertically through the centre of the body.

Worm. The form of condenser still used to a limited extent is that of a metal tube, wound spirally and cylindrically in a tub or vat, through which water is flowing. But its form rendering it difficult of cleansing when choked, the zigzag form, fig. 60, A B C F, has been

Fig. 60.



substituted for the spiral, and, by unscrewing a nut, as H, at G and I, the tube may be cleansed without difficulty. In fact, only every alternate elbow need be opened, and in the fig. the nut and screw at I may be dispensed with. Fig 59, *e*, represents Gædda's excellent condenser, consisting of two inverted concentric cones, joined at their bases and truncations; it stands upon 3 feet in the cooling-vat, and is surrounded with water inside the inner, and outside the outer cone. The difficulty of cleaning the space between the cones being the only objection to this admirable condenser, Mitscherlich makes the inner cone to rest by a flange, like *b* of the helm, on the outer cone, which may be narrowed above and below, and does not allow it to descend to the bottom of the outer cone, which is entirely closed below. A second stream of water is requisite for the latter arrangement, to cool the inner cone. Another form of condenser consists of two sheets of metal brought close together, and might be viewed as Gædda's condenser unwound on a plane.

Peculiar modes of Distillation. When a volatile liquid is to be separated from a relatively fixed body, no peculiar arrangement is requisite, it being borne in mind that the vapor of the volatile body is apt to carry over portions of the more fixed ingredient, and hence violent ebullition in the retort should be avoided, and the distillation not pushed too far, especially where there is an attraction between the distillate and residue. Two liquids, of nearly the same boiling points, cannot be separated by distillation, except by combining one of them in the retort into a fixed compound. Two volatile liquids, of different boiling points, may be wholly separated, unless they possess mutual attraction, when the separation is imperfect.

Essential oils, and other volatile substances, being often decomposed by a temperature but little removed from that of their boiling point, their distillation is effected by means of water, to which they have only a feeble attraction. Although water has usually a lower boiling point than the oil, yet the vapor of the boiling water carries over a portion of the oil, both in vapor and suspended particles; but if it be desirable, the boiling point of the water may be raised, by adding to it salt or chloride of calcium. The recipient contains, after some repose, two distinct layers of oil and water, separable by a syphon or stoppered funnel.

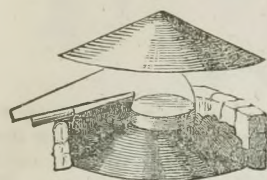
If the two liquids possess mutual attraction, and mingle in all proportions, as alcohol and water, then the boiling point is intermediate between that of the two liquids, and proportionally nearer to that which preponderates.

The distillate contains at first a larger proportion of the more volatile liquid, and hence the boiling point rises during the distillation, until the more volatile liquid has passed over. If this distillate be rectified, the new distillate is still richer in the volatile liquid, and thus, by repeated rectification, the two liquids may be nearly separated. But, however frequently rectified, alcohol still retains a portion of water; moreover, much time is wasted in repeated distillations, and a considerable portion of alcohol lost. The manufacture of alcohol being important in the arts, has been improved latterly in a surprising manner, so that an alcohol of 85 pr. ct. may be obtained by a single distillation. The apparatus first used consisted in principle of several successive stills, a tube from the first passing near to the bottom of the second, and one from this to the third, &c. The distillate from the first condensed as a strong liquid in the second, and the second, being kept boiling by vapors from the first, throws a still stronger liquid into the third, until, finally, a strong alcohol condensed in the worm. As the first portions of distillate are richer in alcohol, and more volatile, so the first portions condensing are less volatile, and on this depends the second method of obtaining strong alcohol by a single distillation. If a still be employed with a series of condensers, arranged above it, so that the condensing liquid may flow back into the still, the first portions condensing will be more aqueous, and, in proportion to the distance from the still, the vapor will be more alcoholic, so that at a certain distance, where the temperature is reduced to about 176°, the condensing liquid is an alcohol, of spec. grav. 0.86. These principles have been latterly combined in one and the same apparatus, as in Pistorius' compound still, which is highly esteemed in Germany. Pl. II., figs. 5, 6, and 7, represents such a compound still, and is described fully under **ALCOHOL**.

Modes of heating. Glass and porcelain retorts are heated in various ways, according to their size, contents, and the temperature required. If the retort be small, it may be heated conveniently over a spirit or gas lamp, by securing the distribution of heat by fine wire-gauze. If of larger size, and a high heat be requisite, it may be imbedded in a sand-bath, and, as a still farther security, be previously coated with clay and sand, and dried. If a uniform and low temperature be necessary, a water-bath is usually employed, and the addition of salt, chloride of calcium or zinc to the water raises its boiling point higher. If still higher temperatures are requisite, an oil bath is most conveniently resorted to.

In distilling oil of vitriol in a glass retort, the deposition of sulphate of lead endangers the safety of the retort and the purity of the distillate by an explosive ebullition. To avoid this difficulty, Berzelius sets the retort $\frac{3}{4}$ into

Fig. 61.



the truncated cone of sheet iron, fig. 61, strews sand around the edge of the cone, surrounds it with brick, and hangs a flat cone of sheet iron about a $\frac{1}{2}$ inch above the retort. The retort is half filled with acid, and coals placed on the cone inside the bricks. Another method he pursues is to precipitate the lead salt by dilution with water, to concentrate the acid in a platinum capsule, and, finally, to distil in a dome-topped furnace, a quiet distillation being promoted by the introduction of platinum wire into the retort.

A copper still may be heated over the naked fire, but it is apt to become injured, and the temperature cannot be uniformly maintained without great care. A far better arrangement is to employ a steam-jacket or casing, which permits a control of the temperature. Steam is sometimes admitted by a tube into the body of the boiler. Large iron retorts are always heated directly by the fire, and are frequently brought to a full red heat.

To work off the distillate rapidly, a retort or still should be much broader than high. If the diameter of the neck be too small, especially at its opening, a portion being cut off will be found to hasten the distillation materially. On the other hand, a too rapid distillation producing a stormy ebullition, portions of liquid are thrown over into the neck, to the injury of the distillate. To avoid this effect, as in general to insure a uniform evolution of vapor, it is often advisable to throw into the retort bits of platinum wire, spangles of iridosmine, or particles of charcoal. In all cases where the liquid in the retort boils, a fine spray may be observed driving through the vessel, and hence a distillate often requires repeated rectification.

DISTILLED WATERS. *Chem. and Tech.* Ordinary water, as found in nature, always contains more or less saline matter, and consequently is unfit for chemical and analytic purposes. When, however, it undergoes the process of distillation, these impurities are left in the alembic, and the more volatile, pure, aqueous vapor passes over into the receiver, and is condensed into distilled water. In chemistry, therefore, distilled water signifies that water which is chemically pure. In pharmacy, the term applies to those aromatic waters which have been impregnated with the volatile odor of plants, by distillation therewith.

DITHIONIC ACIDS. See *Oxacids of Sulphur*.

DIVIDIVI. Syn. Leby-Diby. The hulls of the *Casalpinia Coriaria*, from Carthage, contain gallic acid, and yield pyrogallie by distillation. The tannin appears to be differ-

ent from that in gall-nuts. The quantity of mucilage it contains has hitherto prevented the use of Dividivi in color-printing, but it is largely employed in tanning.

DOLERITE. *Geol.* A basaltic rock, composed of Labradorite and Augite.

DOLOMITE. *Geol. and Min.* See **BITTER SPAR**. As a rock, it is usually more friable than limestone, but is extensively used for building.

DRAGON'S BLOOD. *Chem.* A resinous matter, extracted from the different species of *Calamus*, and from the *Dracena* and *Pterocarpus Draco*. It is red, friable, soluble in alcohol, ether, and the oils, but insoluble in water. Sulphuric acid carbonizes it, and the portion which it leaves undissolved is called *Dracemin*. Its spec. grav. is 1.196, and its composition $C_{40}H_{21}O_8$. Herberger's analysis of its proximate composition is as follows:

Red resin, or <i>dracoin</i>	90.7
Fixed oil	2.0
Benzoic acid	3.0
Oxalate of lime	1.6
Phosphate of lime	3.7

Dracoin or *Dracin* is a tasteless, inodorous alkaloid, of a fine red color, soluble in alcohol, and possessed of the remarkable property in the state of sulphate of detecting the smallest quantity of carbonate of lime in filtering paper, by instantly transmuting the yellow color into red.

When subjected to dry distillation, dragon's blood yields, among other products, a light, colorless oil (*Dracyl*), of spec. grav. 0.877 at 72°. *Dracyl* ($C_{16}H_5$) remains fluid even at 5°, is insoluble in water, but dissolves readily in ether, alcohol, and the oils, and is identical with *metastyrole* (*Blyth* and *Hoffman*), a product of the distillation of *styrole*. *Nitro-dracylic acid* ($C_{16}H_6O_4, NO_4$) is a crystalline product, of the action of fuming nitric acid upon *dracyl*.

DREELITE. *Min. Cryst.* Hexagonal, rhombic, cleavage imperfect; H. = 3.5. G. = 3.2—3.4; white; pearly; fusible to a white blebby glass; partially soluble in muriatic acid. Composed of 75 pr. ct. sulphates of baryta and lime, 8 pr. ct. carbonate of lime, with silex, alumina, and water. It occurs at Nuisiere, near Beaujeu, in France, and resembles chabasie in some external characters.

DROSOMETER. *Chem.* A contrivance of Weidler for estimating the amount of dew deposited upon a given surface during the night, and hence its name, from *δρος*, dew, and *μετρον*, measure. Mr. Wells, in his experiments, used a more simple expedient, and ascertained the proportional deposition of dew, by exposing a weighed quantity of wool, and deducting its acquired from its original weight.

DRUMMOND LIGHT. *Chem.* The dazzling light emitted from lime, which is rendered incandescent by the intense heat of the hydroxygen **BLOWPIPE**. So called from Lieut. Drummond, who first applied it to practical purposes. Its power of giving the prismatic colors, as brilliantly as in the solar spectrum, has procured its use in the gas microscope of Cooper and Carey.

DRYING. *Chem. Tech.* Syn. Desiccation

The entire evaporation of the aqueous portions of a substance, either spontaneously or by artificial means. In chemical operations, a filter may be dried by pressure between bibulous paper with or without the application of heat, the highest temperature usually being that of boiling water. It may also be dried by being placed over or beside a vessel containing oil of vitriol, and the whole covered with a bell glass. The vacuum of an air-pump effects the same, with or without oil of vitriol. The above processes are resorted to where the substance is of an organic nature. If it be associated with an acid that will corrode paper, it may be placed upon a porous tile or brick. Gases are desiccated by passing them over bodies which have a great affinity for water, such as fused chloride of calcium and potassa. See ANALYSIS, p. 176, fig. 24. In technical operations, drying is usually effected on frames, in a heated apartment.

DRY DISTILLATION. *Chem.* A term given to the action of heat on organic bodies in close vessels, whereby the original constituents are metamorphosed into new compounds. Some organic bodies may be distilled without decomposition, alcohol, essential oils, or with partial decomposition; but most are resolved into new products. Much obscurity hangs over this subject, in consequence of not submitting single bodies to dry distillation, for the study of the products resulting from such bodies as wood and coal can never lead to a knowledge of the actual nature of the resulting changes. Hence, scarcely any thing can be said at present of a general character, and we are obliged to refer to special cases to attain a knowledge of the peculiar changes.

By distilling acetate of lead, lime, &c., the operation may be conducted so as to resolve the acetic acid into carbonic acid and acetone, the former remaining united with the oxidized base, thus $\text{CaO}, \text{C}_4\text{H}_3\text{O}_3 = \text{CaO}, \text{CO}_2 + \text{C}_3\text{H}_3\text{O}$. Butyrate of lime, treated in a similar manner, yields butyrene, thus, $\text{CaO}, \text{C}_8\text{H}_7\text{O}_3 = \text{CaO}, \text{CO}_2 + \text{C}_7\text{H}_6\text{O}$. Margarate of lime yields margarone, $\text{CaO}, \text{C}_{34}\text{H}_{33}\text{O}_3 = \text{CaO}, \text{CO}_2 + \text{C}_{33}\text{H}_{33}\text{O}$. Valerate of lime yields valerone, $\text{CaO}, \text{C}_{10}\text{H}_9\text{O}_3 = \text{CaO}, \text{CO}_2 + \text{C}_9\text{H}_8\text{O}$. Similar products are obtained by distilling the acids alone, but the decomposition is more complicated.

When citric acid is heated, $\text{C}_{12}\text{H}_5\text{O}_{11} + 3\text{HO}$, water passes off, then the acid decomposing, a mixture of carbonic acid and oxide, and acetone pass off, and acetic acid, $\text{C}_2\text{H}_3\text{O}_2$, remains; by a farther decomposition of the latter, carbonic acid and itaconic acid are produced, 3 eq. acetic = $\text{C}_{12}\text{H}_6\text{O}_{12}$, producing 2 eq. itaconic, 2 $\text{C}_5\text{H}_3\text{O}_4 + 2$ eq. carbonic acid, C_3O_4 ; by heat, the itaconic is converted into an isomeric acid, the citraconic, $\text{C}_5\text{H}_3\text{O}_4$. By distilling tartaric acid, an anhydrous acid remains, as in the preceding case; by the farther action of heat, it is resolved into two acids, one liquid, the other solid and crystalline. The liquid is formed by the abstraction of 2 eq. carbonic acid and 1 eq. of water, $\text{C}_8\text{H}_4\text{O}_{10}$ (tart. ac.) = $\text{HO} + \text{C}_2\text{O}_4 + \text{C}_6\text{H}_3\text{O}_5$ (liquid pyrotart. ac.); the solid, by loss of 3 eq. CO_2 , and 1 eq. HO , thus, $\text{C}_8\text{H}_4\text{O}_{10} = \text{HO} + \text{C}_3\text{O}_6 +$

$\text{C}_5\text{H}_3\text{O}_3$. The latter is more abundantly formed from alkaline salts of the acid. Malic acid is transformed by heat into maleic and fumaric acids. Meconic acid, with 3 eq. HO , is converted into comenic by loss of 2 eq. CO_2 , thus, $\text{C}_{14}\text{H}_4\text{O}_{14} = \text{C}_2\text{O}_4 + \text{C}_{12}\text{H}_4\text{O}_{10}$ (cryst. comenic), which, by farther heat and loss of carbonic acid, is transformed into pyromeconic acid, as $\text{C}_{12}\text{H}_4\text{O}_{10} = \text{C}_2\text{O}_4 + \text{C}_{10}\text{H}_4\text{O}_6$ (pyromecon).

By the action of heat on starch, it is converted into a gummy substance. Cane sugar, $\text{C}_{12}\text{H}_{22}\text{O}_{11}$, heated to 356° , fuses, forming a yellow, transparent, amorphous mass; at a little higher heat, it browns, and, when heated to 410° to 430° , it loses 2 eq. water, and is converted into a black mass, caramel, $\text{C}_{12}\text{H}_9\text{O}_8$, which is soluble, but tasteless; at a higher heat it loses more water, and becomes insoluble.

By the distillation of fatty bodies, whether solid or liquid, several products result. Thus, stearic acid is converted into margaric acid, and both stearic and margaric acids give rise to margarone, liquid and solid carbohydrogens being produced at the same time. Oleic acid yields, by distillation, gaseous carbohydrogens and carbonic acid, liquid carbohydrogens, and solid sebacic acid. When glycerin is distilled, it yields carbonic acid and inflammable gases, and an acid, volatile substance, acrolein. Hence most fats and fixed oils consisting of two or more of the above acids, stearic, margaric, and oleic, and of glycerin, the above named products are observed when the fatty matters are subjected to distillation. Acrolein proves the presence of glycerin, and sebacic acid of oleic acid.

The distillation of resins has received still less attention than the preceding. Pinic acid (the *alpha-resin* of common resin) is changed into colophonic acid. Common resin yields water, a little turpentine, and an oily body, *resinein*. (*Fremy*.) Thus 2 eq. resin, $\text{C}_{80}\text{H}_{66}\text{O}_4 = \text{C}_{20}\text{H}_{16} + 5\text{HO} + \text{C}_{60}\text{H}_{45}\text{O}_3$ (3 eq. *resinein*). When resin is distilled at a red heat, as in the manufacture of gas, besides the gaseous carbohydrogens it yields an oily liquid, which by redistillation, at observed temperatures, gives rise to various products, an essence passing over between 266° and 320° , a fixed oil at 536° , together with *naphthalin*, and the last, above 700° , is more viscid. The essence yields colorless and volatile *retinaphtha*, C_{14}H_8 , and *retinylen*, $\text{C}_{18}\text{H}_{12}$; the fixed oil, when purified, is *retinoile*, $\text{C}_{32}\text{H}_{16}$; the viscid body, by distillation, yields a crystalline substance, *metanaphthalin*, C_{10}H_4 .

In the distillation of bodies containing nitrogen, ammonia, cyanogen, and more complex principles are obtained. Urea yields cyanic acid, ammonia and cyamelid, while uric acid gives similar products, together with carbonic acid. Oxalate of ammonia yields oxamid and water, by a slow heat, $\text{C}_2\text{O}_3, \text{NH}_3 = \text{C}_2\text{O}_2, \text{NH}_2 + \text{HO}$; but, at a high temperature, water, carbonic oxide, prussic and cyanic acids, and ammonia. Indigo yields, among other products, carbonate and prussiate of ammonia, and kyanole. Xanthanhydric acid, $\text{C}_2\text{NS}_3\text{H}$, yields, by increasing temperatures, rhodanhydric acid, sulphuret of carbon, and cyanhydric

acid, while the residue in the retort is a series of compounds similarly composed, but containing successively less sulphur, until finally melamin remains without sulphur.

By observing the products of destructive distillation, obtained at successively increasing temperatures, on bodies containing carbon, hydrogen, and oxygen, the process appears to be a less or more perfect internal combustion of carbon and hydrogen by oxygen, whence the constant development of carbonic acid and oxide, and water. At lower temperatures, the bodies remaining contain more carbon, which increases proportionally with the temperature, so that when they contain but a small proportion of oxygen, carbohydrogens chiefly result, as in the distillation of oils and resins. The bodies first formed are of more or less complex constitution, and, unless removed from the farther influence of heat, by their volatility, are still farther decomposed by the increasing heat, until the products of decomposition are the more simple bodies, water, carbonic acid, and carburetted hydrogen, the last of which, at a very high temperature, is resolved into carbon and hydrogen.

In like manner, as the separation of oxygen characterizes the distillation of oxygenous bodies, where the substance contains nitrogen, this element is eliminated chiefly in the form of ammonia, by its removing a portion of hydrogen, and the decomposition of ammonia, in presence of carbon, gives rise to cyanogen. Besides these products, complex proximate principles are sometimes obtained, as kyanole from indigo. The presence of oxygen with nitrogen gives rise to some of the products noticed in the preceding paragraph, together with others of a complex character. The final products are highly carbonized.

In the distillation of complex bodies, such as wood and coal, it may be inferred, from all the above facts, that many new bodies would be generated, and the number increased by their mutual reaction during distillation. Either of the two bodies mentioned yield gaseous and liquid matters, and a solid, carbonaceous residue, charcoal. The principal gases from wood are carbonic acid and oxide, and carbohydrogens. The liquid is aqueous or empyreumatic, and oily (tar), the former containing acetic acid, methylic alcohol, acetic methers, lignone, xylite, mesite, ammoniacal products (if nitrogen be present), &c. The oily matter, or tar, contains creasote, paraffin, eupione, picamar, capnomor, pittacal, cedriret, pyren, chrysen, &c.

Coal containing a greater quantity of carbon, hydrogen, nitrogen, and sulphur, than wood, although the immediate products are similar, gas, liquids, and solid, the ultimate products are often different. The residue is coke; the gaseous products are the carbohydrogens, sulphohydrogen, hydrogen, carbonic acid, and oxide. The aqueous liquid contains carbonate, sulphhydrate, cyanhydrate, and chlorohydrate of ammonia; the tarry liquid contains naphthalin, carbolic acid, kyanole, leucole, pyrole, rosolic, and brunolic acids. Of these, carbolic acid (hydrate of phenyl), $C_{12}H_6O_2$, discovered by Runge, has been mi-

nutely studied by Laurent; kyanole, $C_{12}H_7N$, and leucole, $C_{12}H_8N$, discovered by Runge and minutely studied by Hofmann, are alkaloidal bases.

Reference to the several substances named will more clearly exhibit the results of destructive distillation on such complex bodies as wood and coal, and will point out the inferior utility of examining such bodies, compared with those of less complex constitution. If chemists had devoted more time to the thorough investigation of more simple bodies already known, rather than to the thirst for discovering new substances, chemical science would be much farther advanced than it now is, and we would be able to give more general conclusions relative to the effects of destructive distillation.

Tech. On a large scale, bituminous coal is submitted to dry distillation for procuring illuminating Gas; the tarry liquid has hitherto received a limited application; ammoniacal salts and prussiates are obtained from the aqueous liquid, and the purifying lime; the residue, coke, is used for fuel. Where resin or oil is used for the same purpose, the liquids are scarcely used. Wood is distilled to procure pyroligneous acid (Acetic); pyroxillic spirit (see METHYL), is obtained at the same time; the tarry matter is employed alone, or for procuring CREASOTE, &c.; and the residue is a good charcoal. The distillation of nitrogenous animal substances yields nearly all the ammoniacal salts and prussiates employed in the arts. See AMMONIA and CYANOGEN.

DRYING OILS. *Chem. Tech.* Oils which harden by exposure are termed *siccative*, in contradistinction to the *fat* oils, which become rancid, but do not resinify in contact with the atmosphere. In this change, oxygen is absorbed, and carbonic acid evolved, and probably some water and a minute portion of carburetted hydrogen may be formed. A characteristic of the olein of the drying oils is its greater solubility than that of the fat oils, but the distinctive feature of the former oils is developed by hyponitric acid, which, whilst without effect upon their oleic acid, transforms that of the fat oils into elaidine and elaidic acid. A further confirmation of a variation in the two oleins is furnished by recent researches, which show a discrepancy in the ultimate composition of their respective oleic acids, that from olive, and similar oils, being $C_{44}N_{29}O_4$ (HO?), and that from linseed oil $C_{46}H_{38}O_5$ (HO?). The only variation in the proximate composition of the two kinds of oils, is the greater proportion of olein in the siccative oils. The oil *caoutchouc*, mentioned by Jonas (*Chem. Gaz.* vol. 4, p. 476), as the residuum of strongly heated and evaporated drying oils, is formed in quantity directly proportional to their siccative properties.

DUMASIN. *Chem.* Formula $C_{10}H_8O$. Obtained by Kane, as an oily product, with ACETONE, in the distillation of acetate of lime. Heintz, who repeated the process with 2 pts. sugar of lead and one of lime, obtained a body (C_6H_5O), conforming in composition and properties to Kane's mesitic ether, and Berzelius' oxide of ænyle. The discrepancy is attribu-

table to the contamination of the product by the empyreumatic impurity of the wood vinegar with which the lime salt, used in the first examination, was prepared.

DUTCH GOLD. *Tech.* The term properly belongs to an alloy of copper and zinc in certain proportions; but is generally applied to the bronze and copper leaf, which is made in Germany and sold, like gold leaf, in books. See **BRONZE**.

DYEING. *Tech. Ger. Färben. Fr. Teinture.* The art of imparting more or less permanent colors to wool, silk, cotton, and other organized materials.

1. *On Light and Color.* It is immaterial to us at present whether the color be due to the various colored rays reflected from opaque bodies, or refracted through transparent media, since too little is certainly known on this subject. The study of optical effects is, however, important in the combination of colors, as green is produced by combining blue and yellow, violet by blue and red, orange by red and yellow, and various less well-defined hues by other combinations. If the three primary colors, well defined, be mixed, the result is a black, but if in minute quantity or in light tints, a white results. Thus the prevailing natural tint of goods being light brownish yellow or orange, the dyer imparts to them a faint blue or purple, to render them white.

2. *General View.* Some colored substances adhere firmly to organic fibre, and may be termed substantive or self-dyes; others require the aid of another body, called a mordant or color-base, to fasten them, and others again are mere chemical precipitates in or upon the fibre. The stuffs to be dyed are supposed to be without color. The dye-stuffs contain the color to be imparted, ready formed, or to be modified by the use of other agents, and are derived from the vegetable and animal kingdoms, while others are wholly developed by chemical changes. It is exceedingly rare that color is given by a chemical change of the fibrous material itself, as when a yellow is imparted to silk by the transforming action of nitric acid. The usual process with self-dyes is to dip the goods into their solution once or oftener, according to the shade required; with others the goods are passed into the color-base, a portion of which adheres firmly to them, and then into the dye-solution, the depth of color depending on the strength of solution of the color-base or dye, or upon repetition with feebler solutions.

3. *Details of a Dyeing Process.* In dyeing by the older processes, which are still the most numerous, fibre is imbued with a color-base or mordant, and then dyed. For an even light madder red, cotton is imbued with alum or acetate of alumina; for the dark red, with a strong acetic alum solution. It is rapidly dried, and hung up for 8 days to age. It is then rinsed well in cold, and sometimes, at last, in warm water. It is then put into a cold bath of madder and bran, the heat of which, for the 1st third of the time of dyeing, should be but a little over 100°, during the 2d third, about 150°, during the 3d third, it is brought to boiling, and maintained at it for a $\frac{1}{2}$ hour. It is then brightened by being passed through

hot soap water, or a cold dilute solution of carbonate of soda, or a very dilute cold solution of tin-salt. In a somewhat similar manner, yellow colors are imparted by quercitron, French berries, and fustic; a blue or purple by logwood and alkanet; red by Brazil wood and cochineal. Blacks, browns, olives, and other dark shades are similarly obtained, by the use of an iron color-base, or by the mixed bases. But the proportion of goods to dye-stuffs, the temperature of dyeing, the brightening, and other points, of great importance, are peculiar to each substance.

4. *Organic Fibre.* The stuffs to be dyed are wool, silk, hair, leather, &c., from the animal kingdom, and cotton, linen, wood, hemp, &c., from the vegetable kingdom. Since they usually contain coloring matter, grease, and other ingredients, which would more or less impair light and brilliant tints, they are previously cleansed and bleached. See the several articles and **BLEACHING**. They are all fibrous, and on this seems to depend in part their attraction for, or power of retaining various substances, whether between or within the fibres we shall not inquire. Their attractive power is different; thus wool and silk have a stronger attraction for dyes and color-bases than cotton, and cotton again than linen. Their behavior to reagents is also different. Wool will bear the action of strong acids, especially the sulphuric, without injury, while cotton is injured by too long a contact with dilute sulphuric or muriatic acid, but it may remain 24 hours in water with 1 pr. ct. oil of vitriol, if it be immediately rinsed on taking it out. On the other hand, carbonated alkali injures wool by too long contact with it, or if in strong solution, while cotton, dipped into a solution of 1 pt. potash in 4 pts. water, and hung up, is not injured in 3 weeks at a temperature of 68°. Linen is generally less affected by these agents. But they are all more or less injured in chlorine bleaching, which, however skilfully executed, weakens the fibre to some extent.

5. *Behavior of Fibre to Dyes.* When cotton is heated in an infusion of galls or sumach, it takes up a certain quantity of gallic and tannic acids, assuming a light yellowish tint, which cannot be removed by washing with water; catechu thus imparts a reddish brown tint. In the same manner cotton abstracts color from solutions of madder, fustic, quercitron, logwood, &c., from the two first of which the color is strongly marked, and even boiling water will only remove a portion of the color. The solution of any of these colors in water is closely allied to an exertion of chemical force or affinity, and hence when cotton can overcome this force, it is acting by a superior affinity, as shown by its abstracting from solution colors which cannot be removed by washing. The fastness of such colors is therefore due to chemical attraction rather than to mere mechanical adhesion, to which it is usually ascribed. It is probable that many of those dyes which are insoluble, owe their fastness to adhesion to fibre, such as indigo, chromate of lead, and other chemical precipitates. But cotton can take up only a limited

quantity of soluble color, and becomes more or less saturated, so that the attraction of water for the color becomes superior to the attraction of fibre for the same. Moreover, this attraction varies for different colors in the same dye-stuff, for the first pieces of cotton abstract from madder a brownish red, and the latter pieces a yellowish red.

6. *Mordants or Color-bases.* Although fibre takes up some quantity of color from dyes, yet it is insufficient for darker shades, and admits of only a limited variation in hue, but by the use of certain metallic oxides, which have at the same time an affinity for fibre and color, we can obtain darker and more permanent shades, and by the use of different bases, alone or mixed, a greater variety of shades. The 3 chief color-bases are employed in solution as salts, viz., salts of alumina, iron, and tin. Of the two former, the sulphates and acetates are used (rarely the chloride or nitrate of iron); and of the last, the chlorides. To impregnate with base for light even grounds, cotton is simply passed through a very dilute solution of an iron or aluminous salt, and immediately washed in pure water, and, to attain uniformity of ground, it may be passed through twice. For dark or heavy grounds, it is passed through strong solutions, and rapidly dried, as when it is passed over cylinders heated by steam. Goods based with acetate of alumina, after drying, are hung up 6 to 8 days to *age*, whereby deeper colors are attained; but before dyeing they must be well rinsed in water. If cotton be passed through a dilute bath of alum or iron-salt, thoroughly washed, and then through a madder-bath, the color will be much darker and different from cotton simply passed through the madder-bath, from which it is evident that the fibre has decomposed the salts by abstracting a portion of their bases, in the form of basic salts, which water cannot remove. The decomposition of alum (alumina with a large quantity of a powerful acid, the sulphuric), although but partial, proves the exertion of considerable chemical force by fibre. The use of the salts of alumina and oxide of iron is based on, 1, their tendency to form insoluble basic salts; 2, their rendering dyes faster; and, 3, the different colors they assume with the same dye, the salts of the former producing lighter and brilliant colors, and those of iron darker hues. The *aging* of goods, impregnated with acetate of alumina, depends on the continued decomposition of the salt, proved by the constant escape of acetic acid, which leaves a larger proportion of basic salt on the goods, so that, on rinsing, much less of the mordant is washed off.

a. *Alum.* Cotton passed through 3 pts. alum in 180 pts. water, takes up a certain quantity, and apparently no more if the solution be much stronger; but if 1 pt. soda crystals, in a boiling solution, be mixed gradually with the 3 pts. alum also boiling, so that a basic sulphate of alumina is produced, cotton will take up a much larger quantity. When cotton is first galled or sumached, it will also take up a larger proportion of base from alum, and somewhat darker colors may be obtained. See ALUM.

b. *Acetate of Alumina.* Since fibre combines with base by a chemical force, it will assume much more from an acetate than from a sulphate. For the formation of the acetate, see ACETATE of Alumina.

c. *Iron-salts.* Copperas, or protosulphate of iron, and the persulphate are used, and fibre seems to have a stronger affinity for oxide of iron or its basic salts than for those of alumina. But the tendency of the protoxide towards a higher state of oxidation, rather impairs the value of copperas for even grounds. The protacetate is subject to the same inconvenience, the pyrologenate less so. The persulphate of iron is superior to the above, and iron-alum still better. For the formation of the acetates, see ACETATE of Iron; see also sulphates of IRON.

d. The *tin-salts* are used to a much more limited extent in dyeing and calico-printing. For their preparation, see *Chlorides of Tin*. They may be converted into acetates, less injurious to fibre, by acetate of soda, 13 pts. cryst. tin-salt, requiring 17 pts. cryst. acetate of soda, and the perchloride twice as much. See ACETATE of tin. Tin salt is sometimes employed in dyeing for brightening colors, and is especially useful for Turkey red from madder. Besides the brilliant combinations of oxide of tin with dyes, it imparts to them greater fastness.

7. *Indigo Vat.* One pt. indigo is ground fine with water, mixed with 4 pts. caustic lime, slacked, and, to the mixture, 4 pts. copperas, dissolved in water, are added. After standing some hours, the mixture is transferred into the vat nearly filled with water. The usual theory of the operation is that protoxide of iron is precipitated by the lime, and, by its peroxidation, deoxidizes the indigo, which then unites with another portion of lime, forming a soluble compound. When fibrous goods are dipped into the clear solution, and then exposed to the air, the colorless indigo is again oxidized to blue insoluble indigo within the goods. Repetition with a weak vat, or the length of time that the goods remain in the vat determines the depth of shade. This is the most important, and it might also be said the only self-dye, for catechu, &c., are rarely employed alone; but a more minute chemical and technical study of madder and other dyes may yet result in similar vats to that of indigo.

8. *Mineral Colors.* Nearly any chemical precipitate may be fastened upon fibre, with greater or less firmness, by imbuing it first with one solution, drying, and then with the precipitating solution, the process differing from the older modes of dyeing chiefly in the formation in or on fibre, of a color not pre-existing in the materials used. Where the base is alumina, oxide of iron, or other oxide, which fibre has the power of abstracting from its solution, the preparatory step of basing is the same as above given, but if it be oxide of lead, &c., which fibre cannot abstract, it is usual to imbue the goods with the solution, to dry them, and then to precipitate the hydrated or carbonated oxide by passing the goods through caustic or carbonated alkali, or to form an insoluble salt, as the sulphate of lead,

by sulphate of soda. When thus based, the goods are passed through the precipitating solution. A brilliant and fast *yellow* is given by imbuing with acetate of lead, drying, passing through alum or Glauber's salt, to form sulphate of lead, and then through bichromate of potassa. To convert it into *orange*, pass it through a hot solution of 300 gallons lime-water, with 1 lb. yellow chromate of potassa. One of the most beautiful, economical, and rather fast colors is the Prussian *blue*, obtained by impregnating goods with iron-base, (from sulphate or acetate,) aging, washing, and then passing them through a bath of 2 pts. prussiate of potash dissolved in water with 1 pt. oil of vitriol. The tint or shade depends on the quantity of base on the goods; and the color is less easily abraded by passing the blue goods through dilute alum solution, and brightened by exposure to air, or by dilute chloride of lime. It is not uncommon to use a protosalt of iron, and then the blue first appears upon exposure to air or chloride of lime. It is difficult to obtain a good *green* by combining chrome yellow and prussian blue, and it is best attained by making the blue precede the yellow. The brilliant Scheele's, and other allied greens, should not be used on account of their content of arsenic. Chromate of copper produces a *yellowish brown*, prussiate of copper a *reddish brown*, but one of the best browns is obtained from the sulphate or acetate of manganese, by passing goods uniformly through a solution of the salt, and then through a solution of caustic potassa of 14° to 17° B.; it is brightened by boiling with soap-water.

9. *Combinations of Colors and Bases.* Since alumina produces lighter and brilliant colors, and oxide of iron more sombre hues, a mixture of these bases in various proportions enables the dyer to attain a great variety of tints, and shades, and hues, with the same dye. Thus, goods impregnated with aluminous base give a brilliant red in a madder bath, and with a little iron base, a purple, but with a small quantity of iron base and a large quantity of aluminous base together, they give a brownish red, and, with an excess of iron base, a reddish brown. If the employment of different proportions of the two bases gives variety of hue and shade to the same dye, the use of different dye-stuffs with the same base is capable of producing a much greater variety of color; much more than will the use of combined bases and dyes in different proportions produce an almost infinite variety of hue, shade, and tint. Thus, aluminous base gives a brilliant red with madder, and yellow with quercitron, and by mixing the dyes we obtain, with excess of madder, an orange-red, with excess of quercitron an orange-yellow, and by other proportions any intermediate shade. A mixture of madder and logwood gives purple hues; of quercitron and logwood, olive, &c.; a mixture of all three, various browns.

10. *Quantitative Dyeing.* If fibre combines chemically with bases, it exerts, a differing force towards them; for it appears to have a stronger attraction for oxide of iron than for alumina. It appears also that fibre combined with one base, alumina, attracts a larger quan-

tity of another base, iron, than it does of iron alone, so that when cotton is pale-yellowish from iron-alum, it assumes a dark nankeen if previously based with alumina. In like manner a differing chemical force is exerted by based goods towards different dyes in the same bath, so that a larger proportion of one is first abstracted than of another. This becomes evident by successive dyeing; for if 24 pts. of cotton (with aluminous base) be dyed in a bath containing 4 pts. madder, 3 pts. quercitron, and 1 pt. logwood, the color is a good brown, but if the 24 pts. be divided into 4 pieces of 6 pts. each, and successively dyed, the first will be a very dark brown, the second and third successively lighter, the last a light brownish yellow; so also, if 9 pts. cotton be dyed in a bath of 12 pts. madder, in three pieces successively, the first will be a dark brownish red, and the last a pale orange or salmon color, showing that more red is at first abstracted and leaves more yellow at the last. It is also evident that a due proportion must be observed between the goods and dye-stuffs in order to attain determinate colors. The usual practice is to proportion the dye-stuffs to the number of pieces of goods, a considerable error, since the quantity of cotton, by weight, may be double in one piece that which it is in another. The proportion of dye-stuffs to cotton must also vary with the quality of the former: thus one kind of madder may yield twice as much color as another; 3 pts. quercitron-powder, separated by sifting, has the same coloring power as 7 pts. of the fibre. It is a common error with dyers to believe that their experiments can only be made on a large working scale, but it is certain that small experiments, instituted with analytic nicety, would give as correct and reliable results as technical operations, attended with a trifling cost of material and time, as has been proved by eminent European dyers. By accurately weighing dye-stuffs, and cotton, &c., by grains or by ounces, the quality of the former, and the peculiar shade of color, according to the relative proportions of the two, may be determined.

It is remarkable, that when cotton is imbued with a strong acetic alum base, it increases 10 pr. ct. in weight from the base, but that when based with the same solution, diluted with an equal bulk of water, it only increases about $3\frac{1}{2}$ pr. ct., or takes up $\frac{1}{3}$ as much base; and yet the two pieces, dyed in a similar bath, appear to have an equal depth of shade. But if the quantity of dye in the bath be proportioned to the dilution of the base, the resulting colors will also be proportional. It might hence be inferred, that a weaker base would be equally efficient with a stronger, but although the quantity of dye taken up is the same, its fastness is diminished by dilution of the base, except in a few instances. On the other hand, if cotton takes up about 8 pr. ct. base from a strong acetic iron solution, it takes up 4 pr. ct., or $\frac{1}{2}$ as much, from the same solution diluted with as much more water; hence the resulting colors are directly proportional to the dilution of the base.

11. *Brightening.* Both in dyeing and calico printing, substances are employed for altering

the shade of color, or even its peculiar tone, during dyeing or after it. Thus *cow-dung* infusion has been employed from early times in cleansing white grounds, and its main advantage appears to be its property of dissolving away the excess of mordant, and preventing the latter from precipitating on those parts designed to remain white. But it imparts a brownish color itself, and is therefore not adapted to very light tints. For such colors *bran* infusion is better adapted and has a similar action. But besides cleansing the based goods, bran is also used for cleansing on printed and dyed goods, for removing color from the white grounds. But its chief advantage in dyeing lies in its peculiar action in the dye-bath. Thus, for 3 pts. cotton, based with acetate of alumina, add 1 pt. quercitron and nearly 3 pts. bran, to obtain a rich yellow hue; 12 pts. based cotton, 1 pt. logwood and 3 pts. bran give a good purple, which, without the bran, is a purplish brown. Its action with madder is striking. If 9 pts. based cotton, divided into three pieces, be successively dyed in a bath of 12 pts. madder and 36 bran, the first piece has a deep and brilliant red color, and even the third is a rather full red; but if the bran were omitted, the first is a deep, and somewhat brownish red, the second a rather pale and dirty red, and the third a pale and disagreeable salmon hue. Besides brightening the red, bran divides its action more uniformly, and it seems to abstract both the yellow and brown from madder-red. The effect of heating or boiling with *soap-water* is generally advantageous to dyes, and hence this process subsequent to the dye-bath is termed brightening. Both the alkali and the fatty matter in soap seem to act by improving a color and making it faster. The beauty of the Turkey red is in some measure due to the olive oil and potash employed in its manufacture. In the case of bran, the probability is that the phosphate present is the principal agent, and hence the substitution of phosphate of soda (called dunging salt) in calico-printing. Tin salt is also used to brighten some dyes, while it imparts to them greater fastness at the same time. By studying the action of various agents, alkalies, organic acids, and salts, a variety of tones may be imparted to dyed goods.

Conclusion. From the principles above developed, compared with the properties of the dyestuffs, it is evident that the dyer should have a tolerably extensive knowledge of chemical science, in order to improve his practical processes, and place his art among the most beautiful pursued at the present time. The time ought long since to have passed away, that the dyer should despise knowledge imparted by books and scorn the assistance of chemical science; for he is ignorant of the history of the art who does not know that, although the art of dyeing was practised 2000 years ago, and has been carried on with trifling improvement nearly until the present age, it has received the most surprising advancement within the last $\frac{1}{2}$ of a century from the birth of chemical science, with the progress of which it has kept an even pace. The merely speculative artisan, the mere experimenter, cannot be expected to

meet with success, because he keeps out of view the practical bearings of his theories and experiments, looking upon his art rather as subordinate to them, than upon them as hand-maids to his art. Nor can the mere practical artisan meet with more success, except by a natural shrewdness for the accumulation of wealth, and even in this case, it may be inferred that success is partly due to his peculiar theories of processes, which every one is more or less inclined to build up. How much more success would such an one be likely to meet with, if with his natural shrewdness he combined a thorough acquaintance with the theories and practice of pure chemical science upon which his art is established.

DYSKLASITE. See OKENITE.

DYSLUTE. *Min.* Cryst. Regular, 8- and 12-hedron combined, Pl. VIII. fig. 3; cleavage imperfect parallel to 8-hedron, surface rough. $H. = 7.5 - 8$. $G. = 4.55$. Yellowish or grayish brown with a lighter streak; vitreous inclining to resinous; subtranslucent, opaque; fracture conchoidal. Gives the reaction of zinc, iron, and manganese before the blowpipe, and with cobalt solution shows the presence of zinc. Probable form. $ZnO (FeO, MnO) + Fe_2O_3 (Al_2O_3)$; the general form. is RO, R_2O_3 , which is that of Franklinite, which it resembles, with alumina instead of sesquioxide of manganese, and also that of magnetic iron and chromic iron. It occurs in small quantity at Sterling, N. Jersey, associated with Franklinite.

DYSODIL. *Geol.* A polishing slate impregnated with bitumen, the earthy material consisting of silicious coatings of infusory nuclei. It is no true mineral species.

E.

EARTHENWARE. See POTTERY.

EARTHS. *Fr.* Terres, *Gr.* Erden. A term applied to the native compounds of oxygen and certain metals, generally found in pulverulent form. The earths proper are insoluble in water. See ALUMINIUM, THORIUM, GLUCINUM, ZIRCONIUM, and YTTRIUM, and possibly one or two more. The *alkaline earths* have an alkaline reaction, and for these refer to BARIUM, STRONTIUM, CALCIUM, and MAGNESIUM. The properties of each are recorded under their respective heads.

EARTHY COBALT. See COBAL TIC MANGANESE.

EBULLITION. *Chem. Phys.* A term applied to the bubbling commotion of a liquid when it has attained its boiling point and is being converted into vapor. The boiling point is that temperature at which its vapor has sufficient elastic force to overcome the external pressure of the atmosphere upon its surface, and varies in different liquids. The exact point of temperature at which a liquid boils is influenced by several circumstances: 1st, by the amount and fluctuations of pressure; 2dly, the nature of the vessel and its inner surface. The boiling point of the same liquid is always

uniform under uniform circumstances, but when the conditions are altered, as, for example, by covering the boiling vessel, the pressure being partially removed, ebullition is facilitated and takes place at a lower temperature. Marcet has shown, in respect of the boiling point of distilled water in a glass flask, that it varied between 212.4 and 215.6 according to circumstances and the nature of the glass. In passing into vapor, water absorbs a large quantity of latent heat, yet the temperature of the vapor formed is always less than that of the boiling water. In glass this difference averages 1 to 9°. In metallic vessels -0.27° to -0.36°. When, however, the vessel is interiorly coated with sulphur or shellac, the apparent adherence of the watery particles to the glass is overcome, the water boils at 212°, and the temperature of the water is the same as that of the steam. The presence of iron filings, scraps of platinum wire, &c., also decreases the boiling point, as also a rough surface and angular points, which present a greater heating surface and facilitate the escape of gaseous matter. The same chemist remarks, that the temperature of the vapor increases with that of the boiling liquid; furthermore, that the temperature of vapors from saline substances is higher than that from pure water; thus, the vapor of a solution of 25 pr. ct. of common salt, with a boiling point of 221°, has a temperature of 220° in a glass vessel. Radberg, on the contrary, asserts that the temperature of vapor from salt solution is 212°. Glass vessels, whose interior surfaces have been altered by a content of acid or other liquids, are unfavorable to speedy ebullition. If oil of vitriol, for example, has remained some hours in a green glass balloon, in which water previously boiled at 213°, and the vessel is afterwards thoroughly cleansed, then filled with distilled water and heated over a spirit lamp, few or no air-bubbles arise from the bottom, and the phenomenon of singing is scarcely perceptible before 203°. When the thermometer has risen to 212°, a few large steam bubbles separate with difficulty from the bottom, while the thermometer rises to 219.2°. By increasing the flame, the formation of vapor is accelerated, and by lowering it, boiling ceases, and the thermometer rises to 221° and even to 222.8°. When the vessel is heated to redness, ebullition is but partial, even under no more than the ordinary atmospheric pressure, because, above a certain temperature, there appears to be a repulsion between the particles of water and metallic surfaces whereby contact is destroyed. Hence the passage of heat is so retarded that the water boils off slowly. So long, however, as the temperature does not exceed 300° steam is constantly generated. See **HEAT**.

EDELITE. See **MESOTYPE**.

EDINGTONITE. *Min.* Cryst. Quadratic with perfect cleavage parallel to square prism. $H. = 4 - 4.5$. $G. = 2.7$. Grayish white, vitreous, translucent, brittle. Yields water in a closed tube, and becomes opaque; fuses with difficulty to a clear bead; decomposed by chlorohydric acid. It is a hydrous silicate of alumina and lime, but the analysis is too incom-

plete to attempt a formula. It occurs in Dumbartonshire, Scotland.

EDULCORATION. *Chem.* From *edulcoro*, to cleanse. A term applied to the repeated washings of pulverulent substances, with water, for the separation of their soluble matters. It is much used in **ANALYSIS**, (see p. 171,) for purifying precipitates of saline and foreign admixtures. A convenient apparatus for washing precipitates consists of two glass tubes thrust through a cork in a bottle, one of them being drawn out to a fine opening and bent laterally, the other being bent in a syphon form with the longer leg thrust through the cork. The bottle is filled with water and inverted over the filter, which it keeps supplied with liquid only as fast as the latter flows through the filter. In large technical operations, edulcoration is performed by commingling the substance to be cleansed with water, allowing it to settle and drawing off the clear solution through a lead or other syphon. In the arts, the term elutriation is most frequently used.

EDWARDSITE. See **MONAZITE**.

EFFERVESCENCE. *Chem.* From *effervesco*, to boil. The rapid escape of gaseous matter upon the decomposition of certain substances is attended with effervescence or detonation. Effervescence occurs when the elimination is gradual and in bubbles; for example, the frothing of carbonated waters, or the escape of carbonic acid from a decomposed carbonate, or that of hydrogen from water decomposed by zinc and sulphuric acid. The bubbling diffusion of elastic vapor, in general operations, is called effervescence.

EFFLORESCENCE. *Chem.* From *effloresco*, to flower. A property peculiar to certain salts, which, by exposure to air, enflower or crumble. The phenomenon is favorably influenced by a dry and warm atmosphere, and is owing to the evaporation of that portion of the water of crystallization which is not constitutional and requisite for its existence. For example, crystallized carbonate of soda, when exposed, effloresces and becomes coated with a white flowery covering, and eventually falls to powder. The term is also applied to a flowery crystallization of salts upon the surface of bodies in which they are not visible, as, for instance, where nitrate of potassa, soda, or lime, or carbonate of soda, appear upon the surface of soils. Salts thus formed are generated by double elective affinity from compounds existing in the moistened earth, and, being crystallizable, appear at the surface as soon as formed. In this manner originate the saline efflorescences found upon old walls, the nitrate of soda on plains in Peru, saltpeter in various caves, nitrate of lime and potassa in caves in Kentucky, the soda of lakes in Hungary, Egypt, when their water evaporates, &c.

EGGERAN. See **IDOCRASE**.

EGG. *Syn. Fr.* Œuf. *Ger.* Ei. *Lat.* Ovum. The ovum of oviparous animals. Hens' eggs are those generally referred to. When recently laid, their spec. grav. varies from 1.080 to 1.090, but lessens by age, proportional to the loss by evaporation through the pores of the shell. Boiling decreases their weight 2 to 3

pr. et., and coagulates the albuminous or nutritious portion.

Eggs consist of a shell with an adherent tough membrane lining the interior. This is called the *pellicula ovi*, and serves for an enclosure for the *white* or ALBUMEN, which in its turn envelopes the *yolk* or orange-yellow portion. The proportions of each in an egg of 875 grains, as an average standard, are as follows: *Shell* and outer membrane 93·7, *Albumen*, 529·8, *Yolk*, 251·8.

The *shell*, which is the outer covering of the whole, consists of mineral matter cemented together by an animal cement. The proportions vary in different kinds of eggs. Prout's analysis of the shell of a hen's egg gave, carb. lime, 97; phosphate of lime and magnesia, 1; animal matter, 2.

The *white* is a concentrated aqueous solution of albumen. Its accurate composition is, albumen, 12·0; mucus, 2·7; salts, 0·3; water, 85·0 = 100·0.

The *vitellus* or *yolk* consists of microscopic cells containing albuminous matter, which solidifies by coagulation. It is soluble in acetic acid and contains a fixed oil called *oil of egg*, a *viscous matter*, *gray matter*, water, cholesterin, salts, osmazome, traces of lactic acid and iron, and vitellin, and a red and yellow coloring substance.

The viscous matter is connected by an organic entrogenous substance containing sulphur and phosphorus, and encloses the oil of egg, which is separated by means of dilute chlorohydric acid and heat, and subsequently of alcohol. Besides oleic and margaric acids it contains phospho-glyceric acid, the two former in combination with ammonia as a true soap. Vitellin, which forms 16·557 pr. ct. of the yolk, is very analogous to albumen, but differs from it in composition, and encloses phosphates which are difficultly separable. The above components do not exist as a natural emulsion, held in suspension as the yolk by means of albuminous matter, for unlike ordinary emulsions, when largely diluted with water, a separation of its ingredients ensues. (*Comptes Rendus*, 1845.) The *oil of egg* contains cholesterin and some coloring matter, but neither phosphorus nor sulphur.

Yolk, when treated with water, yields a liquid which contains all principles met with in gastric juice;—lactic acid, chlorides of sodium and potassium, hydrochlorate of ammonia, sulphate of potassa, phosphates of lime and magnesia and animal matter. Of the two coloring principles, that which is red seems more soluble than the yellow. The red gave traces of iron, and the yellow is analogous to the yellow matter of the bile. *Gobley*.

According to Liebig, the albumen of the yolk is identical with that of the white, each being of the same ultimate composition, and containing sulphur and phosphorus. The composition of the lining membrane, says Scheerer, is analogous to that of horn; it contains no phosphorus.

ELAIDIN, ELAIDIC ACID. See OLEIN.

ELALDEHYDE. See ACETULE.

ELEOLITE. See NERELIN.

ELASTIC GUM. See CAOUTCHOUC.

ELASTIC BITUMEN. It occurs in soft flexible masses, of blackish brown color, resinous lustre, and subtranslucent, sometimes with a brownish red transmitted light. It fuses easily with decomposition, and burns with a light, smoky flame. Essential oils and alcohol dissolve a slight portion of it; potassa dissolves it readily. The principal part of it seems to be CH. See an allied body, OZOCERITE.

ELASTICITY. *Phys. Chem.* The power possessed by bodies, when their particles have been removed from their original or natural position or volume, by mechanical forces, of returning to the same when the forces are removed. It is exhibited by gases, liquids, and solids, but differently by each. The particles of gas and liquid, having freedom of motion, when subjected to mechanical pressure, are brought closer together, and condensation or diminution of volume ensues, but solids, by virtue of their cohesion, resist both condensation and expansion, their particles tending to return to their original position, when the forces cease which disturbed their position.

The elasticity of gases and vapors is the same, at the same temperature, and at the same distance from their boiling points, their volume being inversely as the pressure. But when we approach their points of condensation to the liquid state, the reaction increases more than the pressure. Liquids are compressible, but no general law for their compression has been obtained, and the amount of it appears to be different for different liquids. Water is compressible the 51 millionth of its bulk for 1 atmosphere, alcohol about the 90 millionth, and ether the 130 millionth. Solutions of gases in water, and acid ethers, are less compressible than water and ether respectively. Compressibility seems to diminish with increasing pressure, and to increase with increasing temperature.

ELATERIUM. *Chem. Phar.* The desiccated juice of the *Momordica Elaterium*. See CUCUMBER.

ELATERIN. *Syn.* Elatin, Momordicin. The active principle of the elaterium is precipitated from a concentrated alcoholic solution of that substance, by the addition of water. The greenish powder is whitened by repeated ablations with ether which dissolves the coloring matter and leaves the elaterin nearly untouched. By crystallization from solution in absolute alcohol it is obtained in lustrous colorless six-sided prisms, insoluble in water, dilute acids and alkaline solutions; scarcely soluble in ether, but readily so in alcohol and the fat oils. Its solutions have no action upon litmus paper. Sulphuric acid decomposes it, and nitric acid dissolves it without alteration, but no definite combinations have been obtained. *Zwenger*.

Its point of prism is 392°, and it loses no weight at this temperature, but, if the heat is increased, decomposition ensues with the disengagement of white corrosive inflammable vapors.

Zwenger's formula is $C_{20}H_{14}O_5$ (?).

ELATHIN. *Chem.* One of the products resulting from the contemporaneous action of sulphur and ammonia upon ACETONE. A

brownish yellow oleaginous body, lighter than water and insoluble in it. It was obtained by Zeise, as one of a series comprising *Thacetone*, *Alcethin*, *Melathin*, *Therythrin*. (Liebig's *Annalen*, 1843.)

ELAYL. *Chem. Syn.* Hydruret of acetyl, Olefiant gas, Etherin. Formula C_2H_2 . Considered by Berzelius as an organic radical and basis of a series of compounds, from its characteristic tendency to combine with bodies both simple and compound, and in this respect differing from other carbohydrogens. It is a constant result of the decomposition of alcohol by sulphuric acid, and obtains its name of olefiant gas from its property of forming an oily product (Dutch liquid) with chlorine.

Prep. One part of absolute alcohol distilled with three parts fused and finely powdered boracic acid, yields elayl without carbonization of the alcohol. (*Ebelmen*.) According to Mitscherlich, when vaporized alcohol is passed into sulphuric acid diluted so as to boil at 320° , it is catalized into elayl gas and water. By Vogel's method of distilling 1 pt. of alcohol with 4 pts. oil of vitriol, the first third of the product is elayl mixed with carbonic oxide; in the second third the quantity of carbonic oxide is increased, and of the last third it comprises nearly the whole.

Prop. A colorless gas, of a feeble, ethereal odor, and spec. grav. 0.9852. It burns with an intensely brilliant white flame; is slightly soluble in water, oil of vitriol, alcohol, and ether, and forms a crystalline compound with anhydrous sulphuric acid, $(C_2H_2 + 2SO_3)$.

Chloride of Elayl. *Syn.* Oil of Olefiant Gas. C_2H_2 , Cl. A very fluid, colorless, ethereal smelling liquid, which boils at 180° , and gives a vapor, whose density is 3448.4. Is readily soluble in alcohol and ether, but only imparts its odor to water, without being sensibly dissolved by it. By distillation with an alcoholic solution of potassa, chloride of elayl is gradually decomposed into chloride of potassium and chloride of acetyl. The continued action of chlorine transforms it into a body, which, by distillation, furnishes two new compounds, one, $C_4H_2Cl_2$, HCl, at 235° , which may be considered as the bichloride of formyl, and another, $C_4H_2Cl_4$ (the tetrachloride of acetyl), at 275° .

Proto-parachloride of Elayl. C_2H_2 , Cl. Formed by introducing into a glass balloon an excess of gaseous chloride of ethyl, with chlorine, exposing to the sun's light and distilling the resulting liquid. It closely resembles chloride of elayl in some of its properties, but differs in others.

Bi-parachloride of Elayl. Formed by heating chloride of methyl, as in the preceding instance. Is an ethereal liquid, resembling proto-chloride of elayl, and composed of C_2H_2 , Cl_2 . *Regnault*.

Iodide of Elayl. C_2H_2 , I. When iodide of ethyl is passed in vapor through a glass tube, at low ignition, it deposits in the cool recipient a reddish brown crystalline powder, which, when purified by potassa and solution in alcohol, crystallizes in yellowish or colorless needles.

Bromide of Elayl. C_2H_2 , Br. A colorless liquid, obtained by passing olefiant gas into bromine. It boils at 265° .

Sulphuret of Elayl. A solution of elayl in alcohol, poured over proto-sulphuret of potassium, gives a white powder, composed of C_2H_2 , S.

Sulphhydrate of Sulfelayl. Obtained by mixing chloride of elayl with tincture of sulphuret of potassium, and distilling off a portion which contains this compound in solution, and which, when added to metallic solutions, precipitates protelayl sulphurets of the sulphuretted metals. Thus the compound of lead has the formula $PbS + C_2H_2$, S. *Löwig and Weidman*.

Bi-sulphuret of Elayl. Tinctures of chloride of elayl and protosulphuret of potassium, by exposure to air, yield this compound, composed of C_2H_2 , S_2 . By boiling with nitric acid it is converted into *Sulfelayl-sulphuric acid*.

Pentasulphuret of Elayl. Formed from a solution of KS_3 , or KS_5 , in alcohol mixed with chloride of elayl, and secluded from air. The yellow precipitate has the composition of C_2H_2 , S_5 .

ELECCAMPANE. *Chem. Phar.* The root of the *Inula Helenium*, according to John's analysis, contains volatile oil, a trace, elecampane-camphor, 0.3 to 0.4, wax, 0.6, acrid soft resin, 1.7, bitter extractive, 36.7, gum, 4.5, inulin, 36.7, woody fibre, 5.5, oxidized extractive with coagulated albumen, 13.9, with salts of potassa, lime, and magnesia.

Elecampane Camphor. *Syn.* Helenin. Classed by Liebig among the concrete volatile principles, analogous to the essential oils. It is a white, crystalline solid, $C_{15}H_{10}O_2$, ($C_{21}H_{14}O_3$, *Gerhart*), obtained by digesting the root in alcohol, or distilling it with water. It passes over as a yellowish oil, which congeals by standing. It crystallizes from alcohol in quadrilateral prisms, fuses at 161° , dissolves in alcohol, ether, creasote, and the essential oils, but is insoluble in water. With nitric acid it yields *nitro-hellenin*, $C_{15}H_9O_2$, NO_4 . When distilled with anhydrous phosphoric acid, helenin loses 2 eq. of water, and gives the carbohydrogen (*hellenin*), $C_{15}H_8$, ($C_{15}H_{13}$, *Gerhart*), a colorless liquid, of less spec. grav. than water. Chlorhydric acid is absorbed at the ordinary temperature, and produces a violet liquid. When chlorine is passed through fused helenin, and the product thickened by alcohol, it yields, on cooling, *chlorhydrate of chlorhellenin* ($C_{15}H_9ClO_2 + HCl$), a yellowish powder, lighter than, and insoluble in, water, and which, when heated with caustic lime, furnishes naphthalin.

Resin. Brown, bitter, and of an aromatic odor, when warmed. Fusible in boiling water, and soluble both in alcohol and ether.

ELECTRICITY. § 1. It was known to the ancients that when amber (*ηλεκτρον*) is rubbed it acquires the property of attracting other bodies. From this phenomenon the modern science of electricity has derived its name.

Nothing, however, of importance was done in this branch of knowledge, until Dr. Gilbert made the experiments which he publishe
A.D. 1600, in his treatise *de Magnete*—a work

remarkable for its sound philosophy, as well as for the value of the contributions it made to physical science.

§ 2. The limits of this article will not permit us to give even a brief history of this science, nor to enumerate in detail any but its more important facts. Boyle, Otto von Guericke, and Newton extended the researches of Gilbert; Gray, by a beautiful series of experiments, was led to the classification of all bodies into *conductors* and *non-conductors* of electricity. And Dufay and Franklin brought forth two rival theories, which serve to the present day, with almost equal merit, to account for the numerous phenomena which they are designed to connect.

§ 3. The theory of Dufay accounts for the known facts of *electricity*, by attributing them to the action of two hypothetical ethereal fluids, called, respectively, *vitreous* and *resinous* electricity; which fluids are supposed to be contained in all bodies, and to neutralize each other, as well as to pass through various substances with greater or less facility. Lastly, the particles of either fluid repel each other, but attract those of the other fluid.

The theory of Dufay was adopted from national partiality in France, and, in the hands of Coulomb, Poisson, and others, has contributed greatly to the advancement of the science.

§ 4. In this article we shall make use of the theory of Franklin, for the reason that it is simpler; that it is better adapted to mathematical expression; and that, while it is in all other respects of equal merit, it commends itself to our preference by virtue of its origin.

Franklin's Theory. The phenomena of electricity are produced by the action of one ethereal fluid, which exists in all bodies. The particles of this fluid repel each other, but attract the particles of matter. The electrical fluid passes freely through conductors, and with difficulty through non-conductors.

When the quantity of the electrical fluid contained in any body is such that the repulsion of the particles of the fluid is in equilibrium with their attraction for the material particles of the body, it is said to be in a *natural* state; but, if more, or less, it is said to be in a *positive* or *negative* state.

§ 5. The theory of Franklin, as it came from its author, and, as stated above, is imperfect in one particular—it fails to account for the repulsion of negatively (resinously) electrified bodies. To remedy this defect, an additional postulate was proposed by Cavendish and Epinus, who both undertook to apply to Franklin's theory the test of mathematical deduction; and who found it necessary to add the hypothesis, that particles of matter repel each other, when without electricity or in the *negative* state.

§ 6. When the facts which constitute any branch of physical science become so numerous that it is difficult, if not impossible, to remember them independently, a theory, by serving to connect them, is useful as an artificial means of memory. And when that theory is capable not only of generalizing known facts, but also of leading to the discovery of

new truths, by suggesting experiments and trains of exact reasoning, it becomes an important auxiliary to experimental philosophy. We should not, however, fall into the error of mistaking the scaffolding for the edifice to be erected; and, still less, treat with contempt all such artificial aids, as is the habit of some, who, not unfrequently, confound together the known and unknown, and speak of the electrical fluid as a reality, instead of as a mere hypothesis to connect isolated facts.

§ 7. The forces of attraction and repulsion which are exerted, and the various effects produced by electricity, render the division of electrical science into the two principal branches of *Electro-statics* and *Electro-dynamics*, alike natural and convenient. Under these heads, and with the following subdivisions, we shall therefore treat of it:

Electro-statics.

1. Development of Electricity.
2. Transference.
3. Attraction and Repulsion.
4. Induction.
5. Distribution.

Electro-dynamics.

1. Effects of Electricity upon Bodies.
2. Atmospheric Electricity.
3. Galvanism.
4. Magneto-electricity.
5. Thermo-electricity.
6. Animal Electricity.

ELECTRO-STATICS.

1. *Development of Electricity.*

§ 8. Electricity is developed, first, by mechanical action; secondly, by physical changes of form and consistence; thirdly, by chemical reactions; fourthly, by magnetism; fifthly, by heat; sixthly, by animal life.

§ 9. Of the mechanical sources of electricity, although mere contact, pressure, &c., give rise to it, by far the most efficient means of producing it is by friction.

When bodies are rubbed together, of dissimilar nature, or under circumstances differing more or less in relation to each, they become *excited* or *electrified*, the one *vitreously* or *positively*, the other *resinously* or *negatively*. According to our theory, the electrical fluid passes from one to the other, giving rise to an excess in the body which receives it, and a deficiency in that from which it escapes. Such, also, is the theoretical explanation of all cases in which electricity is developed.

Although electricity is produced by friction between bodies which differ very slightly, as for instance, two silk ribbons of different colour, or pieces of the same ribbon rubbed together, the one lengthwise, or in the direction of the fibres, and the other across; still the degree and nature of the excitement vary greatly with the substances employed. The greatest excitement seems to be produced by rubbing smooth glass with sulphuret of tin, or with an amalgam of mercury and zinc.

The ordinary electrical machine is merely a glass plate or cylinder, which turns upon an axis, that it may be rubbed by cushions

forced against it by compressed springs; to which is added a "prime conductor," as it is called, for collecting and transferring the developed electricity from the glass to any other body.

§ 10. Electricity is produced by physical changes of form or consistence, as, for instance, when water passes into vapor or steam. Sulphur, when melted, and poured into glass, will, if withdrawn after cooling, show negative electricity, the glass having become positive.

§ 11. When a jet of steam issues from an orifice, from a small opening in the boiler of a steam engine, electricity is developed in great abundance, and may be collected by metallic points, suitably arranged. The boiler usually becomes negative, and the steam positive. This subject has been investigated by Messrs. Armstrong and Faraday, whose researches have led them to the conclusion that the friction between the condensed particles of water and the sides of the orifice is the cause of the excitement. The hydro-electrical machine of Armstrong is used for the development of electricity by this method.

§ 12. Of electricity, developed by chemical agency, by magnetism, by heat, and by animal life, we will treat somewhat fully under electrodynamics.

2. Transference.

§ 13. If an electrified body be touched by another body in its natural state, and the latter be then examined, it will exhibit signs of similar electrical excitement; theoretically, a portion of the electrical fluid of the one flows to the other. If the body touched be positive, it communicates electricity to the touching body, which thus becomes positive; and, if negative, then part of the natural electricity of the touching body passes from it, and both are rendered negative. The forces which determine the result are the attractive and repulsive forces of the particles of electricity and matter, and the state of the two bodies, after contact, is that of equilibrium between these forces.

§ 14. It is evident, therefore, that we can subject the theory of Franklin to the test of mathematical deduction and prediction, if we possess sufficiently accurate means of measuring the degree, as well as of determining the character, positive or negative, of the electrical excitement. The electrometer of Coulomb answers for such measurements with remarkable exactness; and has shown that there is the most perfect accordance between the observed phenomena and our theory.

§ 15. If a body, in its natural state, be connected with an electrified body, by means of a long metallic wire, then the same transference takes place as when the two bodies are brought into immediate contact. But, if we substitute a glass rod for the metallic wire, as the means of connection of the two bodies, then no flow of electricity from one to the other ensues. Hence, we infer that electricity passes freely through metal, and is obstructed by glass—as light is transmitted by transparent, and interrupted by opaque bodies. Many substances

are found to act similarly to the metallic wire, or to the glass rod, with reference to the conduction of electricity, and they are classified, accordingly, as *conductors* and *non-conductors*. No body is, however, a perfect conductor or non-conductor, for all retard and transmit electricity in greater or less degree.

§ 16. If a body be completely enveloped by non-conductors, it is then said to be *insulated*, or in a state of *insulation*. Dry, atmospheric air, glass, silk, and resinous bodies, are among the best non-conductors; while the metals, water, etc., are the most perfect conductors. Hence, any electrified body, supported by glass or resin, or suspended by silk threads, is well insulated, if the surrounding air be dry; but moisture greatly impairs the insulating power of the atmosphere, and experiments therefore fail in damp weather which succeed perfectly in dry. Whenever exact measurements are required, the apparatus employed should be carefully dried, and the hygrometric moisture of the insulating air removed by means of chloride of calcium.

§ 17. The dissipation of electricity from imperfectly insulated and electrified bodies was carefully investigated by Coulomb. He found that the chief causes of loss are, first, the currents of air which pass to and from the excited body, each particle of which becoming electrified, is repelled, and conveys away a portion of the charge. And, secondly, the imperfect non-conducting or insulating power of the supports, which is greatly impaired if hygrometric moisture be deposited on the surface. Coulomb found that the quantity of electricity dissipated by currents of air is directly proportional to the intensity or degree of the electrical charge, and that the non-conducting or insulating power of bodies varies as the square root of their lengths.

3. Attraction and Repulsion.

§ 18. We owe to Coulomb the discovery of the law which governs the action of the forces of electrical attraction and repulsion. By means of his delicate and exact *torsion balance* he was enabled to make observations of sufficient accuracy to determine rigorously that these forces, like that of gravitation, vary inversely as the square of the distance. This instrument, as constructed and used by Coulomb, was composed of a delicate needle of gum lac, suspended horizontally, by a single silk fibre, and carrying on its end a circular disc of gilt paper. Having placed it opposite to, and at different distances from, an electrified sphere, and caused it to vibrate, he found that the times of vibration were directly proportional to the distances. Hence, it may easily be shown that the forces vary inversely as the square of the distance. For, if we denote by t , and t' the times of vibration, and by f , and f' the forces, corresponding, respectively, to any two distances, d and d' ; then, by the laws of mechanics, for the vibrations of a pendulum, we have

$$t : t' :: \sqrt{\frac{1}{f}} : \sqrt{\frac{1}{f'}}$$

Since the times are proportional to the distances

$$\sqrt{f'} : \sqrt{f} :: d : d'.$$

And, therefore,

$$f : f' :: \frac{1}{d^2} : \frac{1}{d'^2}.$$

§ 19. Numerous illustrations of the effects of electrical attraction and repulsion are described in books which enter into the details of the science; and a great variety of toys are employed by popular lecturers for the same purpose. Of instruments, which depend upon these forces, and which are useful in research, we may here mention: the pith-ball suspended by a silk thread; the *electroscope* of Dr. Gilbert, a balanced needle, turning horizontally upon a pivot, with pith-balls on its ends; the gold leaf electroscope; and the torsion electrometer of Coulomb. For full descriptions of these instruments, the reader may refer to almost any large work on electricity. The last is the only one of them which can be used for exact measurements; it depends upon the principle that the angle of torsion is exactly proportional to the force.

4. Distribution.

§ 20. The imperfect obstruction which non-conducting bodies oppose to the motion of electricity renders it extremely difficult to determine what will be the arrangement of an electrical charge which they may receive. Nor can our theory throw much light on this intricate problem; but with reference to the distribution of electricity through insulated conducting bodies, both theory and experiment have contributed to render our knowledge exact.

The balance of Coulomb, owing to its great sensibility, is admirably adapted to the examination of the various degrees of intensity which are observed at different points of any electrified body or system of bodies, and its application to this purpose by its ingenious inventor, forms one of the most beautiful series of researches in physical science.

§ 21. It had been observed that the intensity of the excitement of an electrified body rapidly diminishes when the surface of the body is increased,—as, for instance, by unfolding a sheet of tin foil, wound round an axis, uncoiling a chain, &c.; and, also, that by reversing the operation, the intensity is restored to its original condition. Hence, it was concluded that free electricity occupies only the surface of the bodies.

In the case of a single sphere, it follows, as the result of a simple train of mathematical reasoning, that the particles of a self-repulsive fluid, within a sphere of attractive matter, are in equilibrium, with reference to the sphere. They are, therefore, free to obey their repulsive forces, and must assume their position at the surface of the sphere. Similarly, but not with equal simplicity of demonstration, the same theoretical conclusion has been extended to other less symmetrical bodies. Coulomb undertook to test this conclusion by boring holes of various depths into an ellip-

solid, and examining the electrical condition of the cavities by the introduction of a small disc of gilt paper attached to a filament of gum lac, which he called a *proof plane*. When the ellipsoid was charged and insulated, the disc became highly electrified whenever it touched the exterior surface at any point; but from the cavities, though very shallow, he could obtain not the least indication of excitement. Biot also enveloped an excited metallic ellipsoid within two movable cups of gilt paper, and found, that when removed, the cups contain the whole charge; the thickness of metal in the gilding being sufficient to abstract it entirely.

If two insulated and similar conducting bodies, of equal size, but unequally electrified, be brought into contact, and then separated, they will exhibit equal degrees of excitement, whether they are both solid, both hollow, or the one solid and the other not only hollow, but of extreme thinness, as, for instance, if it be gilt.

§ 22. Although electrical excitement is confined to the surfaces of bodies, yet its degree usually varies greatly at their different relative points. In the language of theory, the fluid is unequally distributed, and is of different *depths* or *densities* at such points. This is readily shown, and exactly measured, by experiments with the torsion balance and proof-plane of Coulomb. At the ends of a metallic cylinder, for instance, the force exerted is found to be much greater than the forces corresponding to the intervening portion, which, as we pass from the ends, decrease very suddenly, but soon attain nearly a constant value. Again, the forces exerted at the middle, and at either of the two ends of an ellipsoid, are to each other in the same ratio as the corresponding axes of the ellipsoid; while, for a sphere, perfect uniformity of force is observed, as its symmetry would lead us to anticipate.

Investigations of this kind, both for single symmetrical bodies, and for systems of such bodies, have served to test the accuracy of our theory in the severest manner, and without showing other than perfect accordance with observation. Although the mathematical problems involved by the distribution of a self-repulsive fluid are extremely difficult, yet, for many of the cases presented by the researches of Coulomb, these problems may be solved; and, in such cases, it becomes practicable to predict the results of experiment with the most minute accuracy. Certainly a theory, which has stood such a test, is worthy of some consideration, and may lead to the discovery of truths of high order, though imperfectly expressed in hypothetical language.

§ 23. Among the most interesting of the explanations of observed facts furnished by theory, is that of the influence of points. It may readily be demonstrated, that if the force be subject to the law of variation in the inverse ratio of the square of the distance, the action exerted by a sphere of attractive or repulsive matter upon an external particle will be the same as if the whole matter of the sphere were condensed at its centre. Hence, if we suppose two metallic spheres, of different

radii, to be connected together by an extremely fine wire, or conducting channel, of indefinitely small diameter, and that a charge is then communicated to one of the spheres, the electrical fluid would, by the repulsion of its particles, distribute itself, and soon attain a state of equilibrium. When it has come to rest, it is evident, if we consider the condition of a particle of the fluid situated in the wire at equal distances from the centres of the two spheres, that this particle must be equally repelled on both sides; and, therefore, that the quantity of electricity upon the surface of the smaller sphere is equal to that upon the larger. Hence, as the surfaces of spheres are proportional to the squares of their radii, the densities, or depths of the fluid on the two spheres, will be in the same ratio; so that if the radius of the smaller sphere be indefinitely diminished, in which case the sphere becomes a point, the density of the fluid with which it is charged will become infinitely great; and since the dissipation of electricity has been shown by Coulomb to be proportional to its intensity, it follows that if the charge be renewed continually it will escape from such a point in a rapid stream, and also, that a current of air will flow from the point.

By reasoning somewhat similarly, we may show that a negative point should exert an analogous attractive influence, with reference to the electrical fluid in surrounding bodies.

Between the conclusions thus deduced from theory, and the facts furnished by experiment, there is the strictest accordance, for it is impossible to accumulate electricity upon a body to which a projecting point is attached; and from such a point the flow of a current of air may be sensibly felt, as well as be rendered manifest by the motion of light bodies against which it may blow. Also, a point is found to draw off silently the electricity of excited bodies, even at considerable distances.

4. Induction.

§ 24. When a positively electrified body acts at a distance upon another body in its natural state, it follows, as a result of theory, that the electrical fluid in the latter will be repelled towards the more remote portion of the body, which will become positive; while that portion which is nearest to the disturbing body will be deprived of part of its natural electricity, and thus be rendered negative.

It is evident from the laws of the forces, that the degree of this influence, or *induction*, as it is called, will depend upon, and be proportional, directly, to the intensity of the charge upon the disturbing body, and, inversely, to the square of the distance between the bodies. Also, by reason of the same law, the distribution of the disturbed electrical fluid will, when it has attained a state of equilibrium, be such as would result from the repulsive action of the electricity of each body, combined with the effect of the opposing attraction exerted by the material particles. Hence, from the negative to the positive end of the body electrified by induction, the consecutive portions will be affected by every intermediate degree

of electrical excitement, the mean or middle portion being in its natural state; or, in the language of theory, the densities of the fluid will constitute a series of regularly increasing values; and these values will be negative on one side of the body, positive on the other, and zero at the middle. In the preceding reasoning, we have assumed the body under induction to be a perfect conductor of electricity; the same conclusions hold good for non-conductors, but in these it is evident that the actual phenomena will be greatly modified by the obstruction offered to the free motion of the fluid.

§ 25. The known phenomena, or facts presented by observation, which are properly classified under the head of *induction*, are too numerous to admit of description in an article of the limits of this. They are all, however, illustrations of the above theoretical proposition. The Leyden jar, the electrophorus, the condenser, &c., depend upon, and furnish beautiful examples of induction, and will be found described in any work which treats fully upon this science.

§ 26. The phenomena of attraction and repulsion are greatly influenced by induction; when, for instance, light non-conducting bodies, such as feathers, &c., in their natural state, are brought near to the prime conductor of an electrical machine, they are attracted and will even adhere to it for a short time, after which they are repelled. The explanation of which is, that, as electricity attracts only unsaturated matter and repels itself, bodies to be attracted must first be acted upon inductively, and, before repulsion can take place, a conduction must have rendered the electrical state of the bodies similar. The latter effect is produced readily in conducting, but with difficulty in non-conducting substances; hence a feather adheres for a time, while a metallic ball is instantly repelled.

By means of induction, and of the law of variation of the forces, with relation to distances, we readily explain the fact that a large and intensely excited body will, at a distance, repel one which is small and feebly electrified, but attract it if near.

§ 27. It is evident that induction can take place only between bodies which are separated by non-conductors. Dr. Faraday has found, however, that different interposed non-conductors cause the degree of induction to vary, or that they possess *specific inductive capacities*. It is remarkable that such differences exist only in solids and liquids, and that with reference to gases, Faraday found all to have the same inductive capacity, a result which was also unaffected by variations of density, temperature, dampness, or dryness.

The researches which led to the discovery of the specific inductive capacity of bodies, were suggested by, and designed to confirm the peculiar views of Dr. Faraday with respect to induction. He supposes that induction is a molecular action, transmitted from particle to particle of the intervening non-conductor, or *dielectric*, as he calls it, in curved as well as in straight lines; or, in other words, that these particles are conductors, which become

polarized, or inductively electrified, and transmit the influence consecutively to each other, and finally to surrounding bodies. This hypothesis has been very generally adopted in England, and the experiments made by its author to establish it are certainly very ingenious; yet, in the opinion of the writer of this article, the observed phenomena require no new theory for their explanation, and may be shown mathematically to be in strict accordance with the old and more commonly accepted views of induction. This opinion is expressed the more deliberately by reason of the high respect which is so justly due to every thing which bears the name of Faraday; an homage, which, in matters of science, is properly rendered, only as the result of careful and independent judgment, open to conviction, but uninfluenced by authority.

ELECTRO-DYNAMICS.

1. *Effects of Electricity upon Bodies.*

§ 28. The effects produced by electricity in motion, and as a source of power, are either mechanical, physical, chemical, or physiological.

§ 29. The mechanical effects of lightning, or atmospheric electricity, are known to, and dreaded by all. On a small scale they may be imitated in the laboratory; glass tubes, for example, with small bores filled with mercury or other liquids, are burst and the fragments scattered, when the discharge of a battery of Leyden jars is sent through them lengthwise; similarly, such substances as crystallized bodies, wood, &c., may be forced asunder.

§ 30. The physical effects relate either to heat, light, or magnetism. The fusion and ignition of bodies by electricity developed by friction are, comparatively, unimportant phenomena, and with some difficulty produced. Very inflammable substances, such as sulphuric ether, turpentine, pulverized rosin, &c., are, however, readily ignited. When the discharge of a Leyden jar is passed through gunpowder, the latter is usually scattered without burning; but if some imperfectly conducting substance, such as a wet string or tube of alcohol, be made to form part of the channel, the gunpowder then inflames readily. Metallic wires may be easily melted by ordinary electricity, if the diameter and length of the wire be sufficiently small.

The ignition and fusion of substances, and the consequent destruction of property, by atmospheric electricity, are facts too familiarly known to need other than a passing allusion to them here.

By galvanism, or electricity developed by chemical action, not only are the most refractory metals, such as platinum, fused, but many of them are consumed and dissipated in the form of oxides. This subject was first investigated by Dr. Hare, of Philadelphia, by means of a large galvanic battery, which he has called a *calorimotor*, from its great heating power, and which we will describe more fully under the head of galvanism. The application of such a battery to the purposes of engineering, in blasting rocks, &c., suggested by

the same gentleman, has been successfully carried out, and enormous masses have been thus moved with great economy and perfect safety.

§ 31. The light developed by electricity, in its passage from one body to another, has not been found to differ in its properties of refraction, polarization, &c., from ordinary light; but its color varies with the substance of the conductors between which it passes, or with that of the intervening medium. This may be in part accounted for by the fact, that whenever an electrical discharge takes place between two conductors, there seems to be an interchange of matter. Electrical light possesses a peculiar power of rendering certain substances phosphorescent; and its phosphorogenic rays are not ordinary light, for they will not pass through transparent glass.

§ 32. By far the most interesting and important fact connected with electrical light, is the discovery, in 1834, by Wheatstone, of the velocity of electricity when it moves through a broken metallic conductor. It had long been known that electricity moves with inconceivable velocity; and it had been observed, that during a storm at night, bodies in motion appear to be at rest, when rendered visible by lightning. The Abbé Nollet passed the discharge of a Leyden jar through 180 of the French guards, who all appeared to feel the shock simultaneously; and the monks of the Carthusian Convent, at Paris, formed into a line of more than a mile in length by wires stretched between them, received a shock at the same moment. Similarly, the members of the Royal Society, passed a discharge through a line of four miles in length, and found, that to all appearances, it traversed the circuit instantaneously.

Mr. Wheatstone employed a copper wire, half a mile long, and broken in three places, at the middle and near each of its ends; these breaks were placed in the same vertical line, opposite to a revolving mirror, moved by clock-work, at the rate of 800 revolutions per second. When the discharge of a Leyden jar was sent through the entire length of the wire, and the mirror was at rest, three sparks were seen to take place simultaneously, and in the same vertical line, as shown in the margin. But when the mirror revolved, the appearance presented by each spark, was that of an elongated line, indicating that the discharge occupies a sensible portion of time, during which, by the angular motion of the revolving mirror, it is reflected in different directions, and is, therefore, seen in consecutive positions: the impressions upon the retina of the eye forming a continuous line, as when a stick is moved rapidly, upon the end of which a spark has been kindled. It was also observed, that the sparks at the two ends of the wire took place at the same instant, so that the extremities of the lines they produced were vertically over each other; while the line of the middle spark lagged behind the others. By measuring this lagging, or lateral displacement, and thence computing the corresponding angular motion of the mirror, Mr

Wheatstone was enabled to measure the portion of time occupied by the discharge in passing through half the length of the wire; and thus to arrive at the fact, that electricity moves through such a channel at the rate of 288,000 miles per second, or with a velocity which is, to that of light, nearly in the ratio of three to two.

§ 33. That the sparks at the two ends of the wire take place, as above mentioned, at the same time, and before that at the middle, has been supposed by some to constitute a valid objection to the theory of Franklin, and to confirm the rival theory of two fluids. But, in all cases of electrical transfer through conductors, we should rather suppose the natural electricity of the conductor to be disturbed, than that the fluid which enters at one end passes through and out at the other. Dr. Franklin aptly illustrated this, by the motion of a stick enclosed in a tube, which, if pushed in at one end of the tube, instantly protrudes at the other, but the change of place of any one of its consecutive portions is slight. The same illustration may aid us in forming a conception of the extreme velocity with which forces or impulses are communicated through a line of connected particles. The middle spark in Wheatstone's experiments is, therefore, to be regarded as taking place only in restoration of the equilibrium of the natural electricity of the wire, the two end sparks being produced simultaneously, one by the transfer to the broken wire of part of the fluid of the highly positive coating of the jar, and the other by the passage of a portion of the natural electricity of the other end of the wire to the negative coating, from which it is no longer repelled, when the channel is opened for the escape of the accumulated fluid of the positive coating.

§ 34. The extreme velocity of electricity, indicated by the experiments of Nollet and others, caused the idea of its application to the purposes of telegraphic communication to force itself upon the minds of electricians, and attempts to carry it out were from time to time made with but little success. The difficulties met with in the use of mechanical electricity, from dampness of weather, dissipation, &c., rendered its employment impracticable, and defeated the efforts of those who sought to avail themselves of it. Galvanic electricity, however, being free from such obstacles, may, and has been of late years, successfully applied to this useful practical purpose, by Steinheil in Germany, Wheatstone in England, and Morse in the United States. The telegraph of Morse has the superior merit of simplicity, as well as of having been the first to register its message by its own mechanism, and thus avoid the errors which would arise from mistakes or neglect on the part of the attendant. Although a knowledge of this telegraph requires information, which it is the object of the subsequent portions of this article to convey, a brief description of it will here be given. The electrical current generated by a galvanic battery at one station, is transmitted to another, by means of a sufficiently insulated wire; at the latter station, the wire

passes round a bar of soft iron, bent in the shape of a horse shoe, or the letter U, which is thus rendered magnetic whenever a current is passing through the wire, but loses its acquired magnetism as soon as the current ceases. The magnetism, thus at will imparted, by causing a current to pass through the wire, and destroyed by interrupting its flow, attracts a piece of iron attached to one end of a lever, and thereby presses a pencil, fastened to the other end, against a strip of paper. This strip of paper is moved by clock-work, under the pencil, and is thus marked with characters, formed of dots, and lines of variable length, according to the time during which the current flows or is interrupted; and conventional combinations of such dots and lines are employed to represent alphabetical letters, numbers, or other symbols. Great credit is due to Prof. Morse, not only for the invention of the simple means by which he has so successfully accomplished a most useful end, but also for the indefatigable energy with which he labored to induce the government of the United States to construct the first telegraphic line between Washington and Baltimore, and thus brought his views to the test of a fair and thorough trial. At present, such telegraphic lines are in operation in the United States, between the principal northern cities, to the aggregate extent of 1500 miles; and others are in progress or contemplation, which will soon connect the most distant cities of our country.

§ 35. Of the magnetic effects produced by electricity, we shall treat fully under magneto-electricity. And the chemical and physiological effects will also be described under the heads of electro-chemistry and animal electricity.

2. Atmospheric Electricity.

§ 36. The identity of lightning and ordinary electricity was first proved by Dr. Franklin. While waiting for the erection of the steeple of Christ Church, in Philadelphia, to enable him to try the experiment of drawing an electrical spark from the higher regions of the atmosphere, by means of a pointed metallic rod, such as is now familiarly known as a lightning-rod, he determined to substitute for the purpose a boy's kite. Accordingly, on the approach of a thunder-storm, in the summer of 1752, he elevated a kite, formed of a silk handkerchief, fastened to a twine or hempen string, and insulated below by means of a silk ribbon. At first but slight indications of electricity appeared, but when the string became moistened by the rain, and its conducting power consequently increased, sparks were obtained in abundance from a key attached to the end of the twine string. Before Franklin had thus succeeded in making this celebrated discovery, he had written to Europe, and proposed the trial of the experiment by erecting a pointed conductor on a lofty steeple; this was accordingly done in France by Dalibard, who thus obtained the first electrical spark from the atmosphere, but, with commendable magnanimity, attributed

the merit of his success to the suggestions of Franklin.

That the sparks thus obtained are ordinary electricity, Franklin proceeded to show, by performing with them various experiments, such as charging Leyden jars, &c. His discovery attracted universal attention, and his experiments were soon repeated by others with improved apparatus, and with results which were often attended with the most magnificent displays of electrical discharge, and sometimes even with great danger. By neglecting the precautions requisite in such experiments for conveying off the electricity to the earth, Professor Richman lost his life.

§ 37. A knowledge of the phenomena of atmospheric electricity is of great importance with respect to the protection of property from destruction by lightning. When a highly excited cloud passes immediately over any portion of the earth, all conducting bodies beneath it will be affected inductively; and, should the cloud pass sufficiently near to permit a discharge to take place, not only will the electricity operate with violence upon imperfectly conducting substances which may constitute part of the channel of its passage, but life may be destroyed even at a distance by the *return stroke*, as it is called, or the sudden restoration of their natural electricity to bodies which have been rendered highly negative by induction. If the discharge passes into the earth through good conductors of sufficient thickness, such as metallic rods, it is not attended with noise or injurious effects; thunder being merely the sound produced by the violent mechanical action of electricity upon the non-conducting air, and precisely similar to the snap of a spark from the prime conductor of an electrical machine. Hence conductors, or the *lightning rods* of Franklin, perform their office of protection by silently carrying off electricity, which would otherwise be destructive.

§ 38. The proper construction of lightning rods is a subject which deserves particular consideration, and with reference to which we will therefore enumerate the principal objects of attention: 1st, The metallic rod should be of sufficient diameter, for the reason that its protecting power is proportional to its size; wires may be fused, and even deflagrated by large discharges. A copper rod, half of an inch in diameter, or one of iron, of three-fourths of an inch, is of sufficient size for any building. 2d, If made of more than one piece of metal, the different parts should be screwed, rivetted, or welded together, that the conducting power may not be impaired by imperfect joints. 3d, It should terminate above in one platinum point. Platinum is requisite to avoid fusion; and, that there should not be more than one point, is evident from the theory of the action of points, given in § 23 of this article. 4th, To enable the electricity to pass off readily into the earth, the rod should connect under ground with conducting masses of as large a size and as perfectly as practicable. In cities, the metallic pipes employed for the conveyance of water and for gas-lighting, furnish excellent systems for the dissipation of

the charge; elsewhere, the rod should pass off through a bed of charcoal, and terminate in a well, or otherwise in metallic plates and in moist ground. 5th, The rod should be elevated to the height of at least one-half of the radius of the space it is designed to protect; for it has been found that beyond that distance it acts imperfectly.

For the protection of houses with metallic roofs, Professor Henry has recently called attention to the fact, that it is simply necessary to connect the metallic pipes used to carry off rain, by copper ribbons, with any system of conductors adapted to convey it readily into the earth.

Magazines for gunpowder should be protected by several rods elevated upon masts, and great care should be taken to secure the free passage of the electricity through sufficient conductors into the earth.

Ships are sometimes furnished with conductors, either passing in grooves down the masts or suspended from the yards, and terminating, by metallic union with the copper sheathing, or merely by contact with the water.

§ 39. The subject of the *lateral discharge*, as it has been called, has been much discussed of late years in England, and particularly in its relation to the lightning rods invented by Mr. Harris, and used for the vessels of the British navy. It was maintained by Mr. Harris and his friends, that electricity, in its passage to the earth, always follows the path of least resistance, and upon the correctness of this opinion the merit of his system depends. Others contended that lateral explosions to surrounding bodies may, and often do occur, when a discharge passes through conductors; and, therefore, that it is unsafe to convey the electricity through the hold of a vessel, and near to the powder magazine, as in the plan adopted by Mr. Harris. Both parties appealed to experiments to sustain their respective views, but the discussion led to no new and important facts. It has long been known, that when a powerful Leyden jar or battery is discharged through a metallic wire held in the hands, a shock is often felt, and the effect was by some supposed to be owing merely to obstruction. Professor Henry communicated to the British Association, in 1837, the fact, that when electricity is thrown upon a lightning rod, from a machine, sparks may be drawn from any part of the rod. And he has since shown that the lateral discharge is due to the passage of a wave of electricity, which tends to escape from the surface of the rod to neighbouring bodies. Hence, that a lightning rod may be so arranged as to avoid the consequences of lateral discharges, all detached conducting bodies should either be sufficiently removed, or so connected with it by metallic ties as to form one conducting mass.

§ 40. The sources of atmospheric electricity, and the method of its accumulation, are subjects to which considerable attention has been paid, but of which little is yet known. They properly belong to meteorology, and to works upon that science we may therefore refer. The researches of M. Pouillet have established the fact that large quantities of

electricity are developed by evaporation, especially from salt water; also, that combustion and vegetation produce like effects: but of its accumulation in clouds, we know nothing. Indeed, the formation of clouds themselves is a subject which has not been sufficiently studied, and of which the views of Mr. Espy have furnished the only physical theory. That theory may now be regarded as established for a numerous series of observed facts; but it needs to be extended, to account for the electrical phenomena of storms.

§ 41. The various facts which are usually observed during thunder-storms, such as the zig-zag path of lightning, the sudden clap of thunder, its loud, continued and rolling report, and the subsiding mutter, are all readily explained by the known laws of electricity and sound. These phenomena constitute very interesting subjects of observation, but they are too numerous for description here; we will, therefore, give only the method of ascertaining the distance at which any discharge of lightning takes place. Observe the instant of the flash; then count the seconds marked by a watch, or the number of pulsations of the artery of your wrist, which occur before the thunder is heard; allow five seconds to each mile, and you have the distance nearly.

§ 42. The electro-magnetic telegraph is often greatly disturbed, and sometimes even injured, by atmospheric electricity. The disadvantages are usually the interruption of communications during the existence of the disturbance, but violent effects even prove destructive to the apparatus. The insulated wire may be struck by lightning; or it may transmit electricity between differently electrified regions of the atmosphere; but it is most frequently operated upon inductively, and especially during storms. The phenomena which are thus presented, are objects both of practical and scientific importance, and they should therefore be carefully observed and studied.

3. Galvanism.

§ 43. *Galvanism* is the term usually applied to electricity developed by chemical action, and which was at first regarded as entirely different from ordinary electricity. It derives its name from that of Galvani, professor of anatomy at Bologna, whose experiments on the convulsive effects produced by electricity upon the muscles of dead animals, first drew attention to the subject. This kind of electricity is also frequently called *Voltaic*, in commemoration of the discovery of the Voltaic battery or pile by Professor Volta of Pavia, which established the identity of galvanism and ordinary electricity.

§ 44. When a plate of zinc is immersed in acidulated water, a chemical action takes place between the zinc and the water, and their electrical equilibrium is disturbed; the water becomes positive, and the zinc is rendered negative; in theoretical language, part of the natural electricity of the zinc passes to the water. And if the zinc be pure, or amalgamated with mercury, all chemical action ceases, when the forced electrical condition

has attained its full development or degree of tension. If, however, a plate of copper, or any other less oxidable metal, be then immersed in the acidulated water, and it be connected with the zinc by soldering, or close contact, so that electricity can pass freely between the two metals, the free electricity will be collected from the water and conducted by the copper back into the zinc. Both the zinc and the water being thus restored to their natural state, the chemical or *electromotive* force immediately acts again between them, and another portion of electricity is set free, which in turn is conducted back by the copper. It is evident, that a constant current of electricity will thus be established, which will flow from the zinc to the water, and thence return through the copper to the zinc, of which current the chemical action between the zinc and the water is the *electromotive force* or exciting cause.

§ 45. The acid, usually sulphuric, is added to the water to remove the oxide of zinc, which is formed by the chemical action between the water and zinc; this oxide would otherwise form an insoluble crust upon the metal, and mechanically prevent its contact with water; when the zinc unites with the oxygen of the water, its hydrogen of course escapes. The acid has also been supposed to exert a *predisposing* or *inducing* affinity, (see *AFFINITY*,) and thus to render the combination of the oxygen with the zinc more rapid.

§ 46. The physical theory of galvanism was long a matter of discussion and uncertainty. Volta attributed the development of electricity which occurs to the contact of dissimilar metals; and Galvani had erroneously supposed it to be due to physiological agency. The researches of Faraday have, however, fully proved, that chemical affinity is the disturbing or electromotive force. These researches will be treated of under the head of *ELECTRO-CHEMISTRY*, to which we therefore refer; which subject properly constitutes a branch of chemistry, and is therefore excluded from this article, in which we propose to discuss electricity as a part of the science of pure Physics; it may, however, be considered as the common property and bond of union of the two sciences.

It is evident, if a closed circuit formed, as above described, of zinc, water and copper, always produces a current of electricity which circulates within it, that the observed physical effects will be accounted for equally well by supposing the current to set out from, and be generated at, either the points of contact of the two metals, or the moistened surface of the zinc plate. Hence, the chemical effects of galvanism alone indicate its dependence upon chemical affinity as its true physical cause.

§ 47. *Simple Galvanic Circles*. An arrangement, composed of a single pair of metallic plates and an intervening liquid, or of three elements, is usually called a *simple galvanic circle* or *battery*. It matters not what form may be given to the battery, or its elements, nor whether it be even composed, as is frequently the case, of a very large number of pieces of copper and zinc, if

they be so connected by conductors as to constitute virtually one zinc element, and another of copper. Nor is it necessary that the battery be formed of two metals and a liquid; any three bodies, or systems of bodies, between two of which chemical affinity causes the development of electricity, while the third acts as a conductor to restore the electrical equilibrium, constitute a simple galvanic battery. The substances employed may, therefore, be almost indefinitely varied, alike in their kind and in the mode of their arrangement.

§ 48. The electricity developed by a simple galvanic battery is enormous in quantity, but of very feeble intensity. Faraday found that two wires, one of zinc and the other of platinum, each five-eighths of an inch long and one-eighteenth of an inch in diameter, yielded, when immersed in acidulated water, as much electricity in three seconds as was obtained by thirty revolutions of a plate machine, fifty inches in diameter, or required to charge a Leyden battery of 3500 square inches; and the quantity of oxide of zinc formed to produce this result could not have been appreciable by means of the most delicate balance. He has also shown, that the quantity of electricity developed during the chemical decomposition of a grain of water, cannot be less than that which is contained in the most powerful flash of lightning. And yet so slight is the intensity of galvanic electricity, that it will pass only through the best conductors, and requires condensation to give even feeble indications of attraction and repulsion; its mechanical effects are therefore trifling, while its chemical and physical effects are powerful and important.

§ 49. It is evident, since chemical action is the cause of galvanism, and the electricity produced, therefore, proportional to the amount of zinc consumed, that by enlarging a simple galvanic circle, we increase in the same ratio the quantity of electricity it will yield. The intensity of the electricity of such a battery, however, depends upon the energy of the chemical affinity, which is constant between any two kinds of matter, and can therefore be changed only to a very limited extent, and by varying the substances which compose the battery.

§ 50. *Compound Galvanic Circles.* Since galvanic differs from ordinary electricity, only in relative quantity and intensity, it follows, that to render their respective effects comparable and establish their physical identity, some means of increasing the intensity of galvanism was necessary. Volta, by reasoning clearly upon this subject, was led to the discovery of the *compound galvanic circle*, or battery.

If we denote by z, a, c , the three elements of a battery, and suppose the electricity generated between z and a to be conducted by c , not, as in simple galvanic circles, back into z , but onward to z' , the corresponding element of a similar arrangement, z', a', c' , then it is evident that the electromotive force between z and a will co-operate with, and be added to, that existing between z' and a' ; so that by increasing the number of similar arrangements, and connecting c with z' , c' with z'' , c'' with z''' , and so on, we may develop electricity of any desired degree of intensity. If z, a, c ; z', a', c' ; z'', a'', c'' ; &c., be similar arrangements, the intensities $e, e', e'',$ &c., of the electricity generated by each will be equal; and $e, 2e, 3e, 4e,$ &c., will express the respective intensities of the electricity, collected and conducted onwards by the consecutive elements, $c, c', c'', c''',$ &c.

For the reason, however, that electrical development by chemical action ceases very quickly, and as soon as it has attained a certain degree of tension, it is necessary to form a circuit, in order to restore to $z, z', z'',$ &c., their natural electricity and produce a continuous current. This is readily done by connecting the last conductor, c^n , with z ; by which the accumulated electricity, $(n+1)e$, will be transmitted in constant circulation through the entire series. To such a system of combined elements, the term *compound galvanic circle*, or *battery*, is applied.

The first and the last elements, z and c^n , of any battery are usually called its *poles*; z being called the *negative*, and c^n the *positive* pole. Faraday and others have also named them *electrodes*, and, respectively, the *zincode* and *platinode* of the battery.

§ 51. The various forms which have been given to simple and compound galvanic batteries are exceedingly numerous; and the limits of this article will not permit us even to describe those which are commonly known. The reader is, therefore, referred to more extended treatises on electricity, for a full account of them.

The Voltaic pile, formed of successive discs of silver, zinc, and moistened cloth—the *couronne des tasses* of Volta, a series of cups partly filled with acid, and containing each two plates, the copper being connected with the zinc of the succeeding cup, the *calorimotor* of Dr. Hare, and the *constant battery* of Daniell, deserve particular notice, in consequence of their connection with, and the influence they have exerted upon, the progress of this branch of electrical science. The *calorimotor* is a large simple galvanic circle, conveniently arranged in a spiral form for producing powerful calorific effects; these we will treat of under the head of the *physical effects* of galvanism.

§ 52. The *constant battery* of Daniell is designed to remedy the defects of an ordinary battery; these defects, which cause the electromotive action to subside rapidly, and soon to cease altogether, are: 1st, The sulphuric acid becomes saturated with the oxide of zinc. 2d, The hydrogen adheres to the surfaces of the metals, and thus prevents their perfect contact with the water. 3d, By the chemical action of the battery, (see ELECTRO-CHEMISTRY,) the zinc, contained in the sulphate of zinc which is formed, is reduced to the metallic state at the surface of the copper, and deposited upon it in the form of a crust, where it acts locally and impairs the conducting power. 4th, Electricity is carried off and dissipated by the escaping hydrogen.

The adhesion of hydrogen to the zinc plate does not take place when that metal is pu

or amalgamated with mercury; Daniell, therefore, employs a cylindrical rod of amalgamated zinc, instead of a plate of the common and impure metal. But the peculiar and most valuable feature of his battery is the use of a *porous partition*; which may be formed of animal membrane, earthenware, plaster of Paris, paper, or any like substance; and which divides the vessel containing the metals into two cells, one of which, the zinc cell, is filled with dilute acid, and the other with an acid solution of sulphate of copper. The partition freely transmits the electrical current, but prevents the passage of the sulphate of zinc to the copper plate, and thus remedies the third of the above-mentioned defects. The sulphate of copper is decomposed, and must, therefore, be continually renewed, by placing crystals of it in the copper cell; while the nascent hydrogen unites with the oxygen of the oxide of copper, forming water, and therefore does not interfere with the action of the conducting plate, nor carry off electricity.

§ 53. Grove's battery is another, in which, as in that of Daniell, the metals are separated by a porous partition. It consists of an amalgamated zinc plate, connected with one of platinum, and is charged with dilute sulphuric acid in the zinc cell, and with strong nitric acid in the platinum cell. This battery acts very energetically, in consequence of a chemical action between the two acids through the partition, which develops a supplementary current in the same direction as that produced by the zinc plate. Bunsen's battery is an economical and excellent modification of that of Grove, in which an element of artificially prepared carbon is substituted for the platinum plate; cast iron has also been employed for the same purpose.

§ 54. The power of any battery is evidently proportional directly to the electromotive force, and inversely to the resistance to be overcome. Hence, to express these conditions, Prof. Ohm has given the valuable formula,

$$A = \frac{ne}{r + nr'}$$

In which A denotes the effective power; n , the number of generating cells; e , the electromotive force; r , the resistance of the conducting metal; and r' , the resistance of the liquid in a single cell.

If the poles be connected by a conducting wire, the resistance, r , is proportional to the length of the wire, and inversely to its sectional area. But, if the wire be many miles long, the resistance it opposes to a transmitted current varies arithmetically as the length of the wire increases geometrically, according to experiments of Prof. Morse made upon the wires of his electric telegraph.

The resistance, r' , is proportional to the thickness of the stratum of the liquid, and, inversely, to its conductivity and to the mean surface of the two plates.

§ 55. It is important to a clear knowledge of galvanic phenomena, that the office and electrical state of each of the different parts of a battery should be distinctly comprehended;

for much confusion has resulted from inattention to this matter. In a simple battery the current passes constantly from the zinc plate, which becomes negative, to the copper, which is therefore positive. But in a compound battery, formed of pairs of plates, the zinc plate of the first cell is attached to a terminal copper plate, and, similarly, the copper plate of the last cell is united to a terminal zinc plate; the conducting wires are connected with these terminal plates. The current is therefore conducted from a positive zinc to a negative copper plate, and the electrical order is apparently reversed. As the terminal plates form a superfluous part of the conducting channel, they may be dispensed with, and should, theoretically, be disregarded. All indistinctness vanishes when the fact is borne in mind, that the conducting metal constitutes the positive pole, and is designed to restore the developed electricity to the generating metal, or negative pole.

§ 56. *Effects of Galvanism.* Galvanic differs from ordinary electricity, as we have already stated, in three important features, its immense quantity, its feeble intensity, and its gentle flow in a circulating current. It is therefore evident, that its action on bodies must differ widely in many respects from that of ordinary electricity, which, owing to its great intensity, moves with extreme velocity, and produces violent mechanical, but feeble chemical and physical effects.

The mechanical effects of galvanic electricity are so very slight, that they can be rendered evident only by compound batteries of a considerable number of plates. The divergence of the leaves of the gold leaf electroscope, with positive or negative electricity, when brought into connection with the corresponding pole of a battery; the spark which passes between the poles; the feeble electrical charge communicated to a jar or battery; and the galvanic *shock*, are the principal phenomena analogous to those of mechanical or ordinary electricity, which were discovered by means of the pile of Volta, and which enabled him to prove the identity of the two agents.

The chemical effects of galvanism constitute that branch of science now usually called **ELECTRO-CHEMISTRY**, to which article we therefore refer.

The physical effects we shall discuss under the following heads: Development of Heat and Light; Electro-dynamical Induction; Action of Currents on Currents, or Electro-dynamical Attraction and Repulsion.

§ 57. *Development of Heat and Light by Galvanism.* When a current of electricity, of great quantity but of feeble intensity, passes through an insufficient conductor, the latter becomes heated to a high degree. We have already stated (see § 30), that gunpowder, when subjected to the discharge of a Leyden jar, does not readily ignite, unless some imperfect conductor, such as a tube of alcohol, forms part of the conducting channel through which the discharge takes place. Hence it appears, that resistance causes retardation and tends to increase the calorific power of

an electrical discharge; and this conclusion is confirmed by the analogous phenomena of galvanic electricity.

When the remarkable heating power of the calorimotor of Dr. Hare first drew particular attention to this subject, it was supposed by many that such results as the fusion and deflagration of metals could be produced only by large and very powerful batteries; Dr. Wollaston established the contrary by means of a very small battery, made of a lady's thimble, with which he fused a capillary platinum wire; and he thus proved that the only condition requisite to the development of intense heat is, that the conducting wire should be of insufficient size to transmit freely the quantity of electricity generated by the battery.

The light emitted by the deflagration of metals at the poles of a battery varies in color with the nature of the metal. Thus silver produces a beautiful green light, copper a bluish white with red sparks, and lead a beautiful purple.

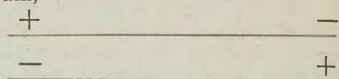
When the poles of a battery consisting of a numerous series of large plates, so as to develop an electrical current of considerable quantity and intensity, terminate in charcoal points, the most brilliant light which can be made artificially is emitted whenever these points are brought into contact. And, if they be gradually drawn apart, the current will still continue to flow between them through the rarefied air, even at the distance of several inches, forming an arch of light of dazzling brightness, in which the most refractory substances are either fused or deflagrated. This light is not produced by combustion, for the charcoal is not burnt, and the two points weigh nearly the same both before and after the experiment, though there is a transfer of matter from one to the other in a vitrified state. A singular fact in relation to this arch of light, the explanation of which will be obvious when we shall have discussed the phenomena of electro-magnetism, is its rapid rotation when subjected to the influence of a magnet.

§ 58. *Electro-dynamical Induction.* It is evident from the nature of the phenomena which we have discussed under the head of *Induction*, in § 24—27, that electricity in motion must produce analogous effects. By reason, however, of the variations in position, intensity and time, which occur as necessary consequences of motion, the phenomena of dynamical induction are much more complicated.

This subject was first partially studied by Faraday, in England; and it has since been thoroughly investigated by Prof. Henry, in our own country, who has succeeded in showing, that the phenomena of statical and dynamical induction are similar, and equally deducible from the Franklinian theory. According to that theory, §§ 4, 5, all matter is presumed to be saturated with a self-repulsive fluid; supposing this natural electricity of bodies, or electrical plenum, to obey the laws of fluids, and therefore to return to equilibrium when disturbed by a series of oscillations, or waves, Prof. Henry explains all the known facts of dynamical induction by referring them to es-

tablished principles of mechanics and of statical electricity.

In the case of the discharge of a Leyden jar through a wire, for instance, he has shown, that at the moment of the discharge the electrical conditions of the two portions between the middle and each end of the wire are opposite, the one being positive and the other negative, (see § 33,) and that at each succeeding instant the conditions are reversed, the positive end of the wire becoming negative, and the negative end positive. Thus, a series of oscillations of decreasing intensity is established, by which equilibrium is gradually restored. And if a number of wires be arranged parallel to that employed to discharge the jar, and to each other, it is found by experiment and is also evident from theory, that when the electrical condition of the primitive wire is represented by *plus*, *minus*, the corresponding induced state of the second wire will be *minus*, *plus*, as illustrated by the annexed diagram,



Similarly, each oscillation, or reflex current in the primitive wire, induces an opposite wave in the second: these secondary waves give rise, inductively, in the next wire to waves of the third order; which, in turn, produce waves of the fourth order; and so on, successively, through the entire series of parallel wires.

Dynamical induction, produced by electricity of such intensity as that developed by friction, extends to remarkable distances. In the experiments of Prof. Henry, discharges from a jar, through a wire arranged in the form of a parallelogram around the ceiling of his laboratory, magnetized needles in a spiral which formed part of a similar parallelogram on the floor of the cellar, 30 feet below; and the same effect was in like manner produced by the secondary current in a wire parallel to the primitive wire, at the distance of 300 feet. Similar results were obtained from atmospheric electricity, by means of a copper wire attached to the metallic roof of his house and terminating in a well; at every flash of lightning which took place within a circle of 20 miles needles were magnetized in a spiral, which formed part of the wire.

§ 59. If the direction of an induced current be indicated by the polarity of a steel needle magnetized in a spiral, Prof. Henry finds that this direction is reversed: 1st, with a variation of distance between the two parallel wires; 2d, with a change of the quantity and intensity of the discharge; 3d, with the proximity of a third parallel wire, forming a closed circuit; 4th, with an opening in the wire of the induced current. These facts are readily explained by the above-mentioned theoretical principles, § 58; for successive waves, or reflex currents, should magnetize a needle, alternately, with opposite polarity. A change of distance between the wires, by producing a corresponding variation of intensity, must render the induced waves more or less effective; at great dis-

tances, the action of the first oscillation alone may therefore be appreciable, but, when the two wires are close together, a wave of the second, third, fourth, or n th order will produce equivalent results. An opening in a wire which is readily overcome by the first wave may sufficiently resist and prevent the passage of the second, &c.

§ 60. Inductive phenomena, similar to the above, are also produced by galvanic electricity, in its passage through the conducting wire of a battery, whenever the current varies in its quantity or intensity so as to cause an electrical wave to take place. And these phenomena have been referred by Prof. Henry to the same theoretical principles (§ 58), which he has established for the dynamical induction of ordinary electricity.

The poles of a battery in action are kept by the electromotive force in a state of tension, or are oppositely electrified, so that the condition of the battery may be compared to that of a charged Leyden jar. If these poles be then connected, by means of a copper wire, the positive pole imparts to one end of the wire its excess of electricity, and part of the natural electricity of the other end of the wire passes at the same time to the negative pole; thus the two halves of the connecting wire are in opposite states, one becoming *plus*, and the other *minus*. Hence, it is evident, that all the inductive effects caused by the discharge of a jar, and exhibited by a system of parallel wires, as described in § 58, must also be produced at the instant when the poles of a galvanic battery are connected by means of one of those wires. As galvanic electricity is, however, of very feeble intensity, the induced waves of the third, fourth and higher orders, to which it gives rise in parallel wires, should be slight at considerable distances, unless the number of plates of the battery be so large as to develop electricity of sufficient intensity.

When the current of a battery is fully established, so that it flows uniformly, no waves or dynamical inductive effects will be produced in a fixed parallel wire. As the two ends of the conducting wire are, however, in opposite states, one *plus* and the other *minus*, statical induction should take place, the intensity of which, at a given distance, will be proportional to the difference in intensity of the two ends of the primitive wire. But if the distance between the wires varies, the inductive action will also vary (§ 24) inversely as the square of that distance; and by moving either of the wires to or from the other, induced waves in opposite directions will, therefore, be produced.

A change in the quantity of a galvanic current is produced by moving the zinc plate so that it shall be immersed to different depths, and expose corresponding extents of surface to the action of the acid. During the motion, dynamical induction takes place, and the secondary currents induced by increasing and decreasing the active surface, are in opposite directions.

§ 61. One of the most important and interesting phenomena relating to this subject, is the fact that a current of quantity can induce

one of intensity, and, conversely, an intensity current can give rise to one of quantity. To render this, and other inductive effects of currents of different orders manifest, Prof. Henry made use of several spirals, or flat coils of sheet copper, some an inch and a half, others three-fourths of an inch wide, and from sixty to a hundred feet in length; and of helices or spools of copper wire, $\frac{1}{10}$ th of an inch in diameter, and from three hundred and fifty to sixteen hundred and sixty yards long; also, of a similar helix of silvered copper wire, $\frac{1}{12}$ th of an inch in diameter, and fifteen hundred yards in length, and of a large spool of copper wire, $\frac{1}{16}$ th of an inch in diameter, and five miles long, wound upon a small iron rod or axis. The coils were wrapped with two coatings of silk; the wires with cotton thread saturated with beeswax, and the successive strata of the helices were separated by silk coatings; so that perfect insulation of the convolutions was obtained.

When one of the above-described ribbon-coils is employed to transmit the current of a galvanic battery, it will induce in a similar coil a current of quantity, but if it act inductively upon one of the long wire helices, the secondary current will be one of intensity. In like manner, a current of intensity in one of the helices will induce a current of quantity in a ribbon coil, or one of intensity in a helix. The intensity currents will be capable of giving shocks, like those from a Leyden jar, and the quantity currents of producing deflagration and magnetic effects.

It is evident, that ribbon coils, like those of Prof. Henry, are well adapted to transmit currents of quantity, by reason of their comparatively short lengths and large sectional areas; while long wire helices present so strong a resistance, that currents of intensity alone can flow freely through them. Such coils and helices are also far better suited for the investigation of the dynamical effects produced in parallel conductors, than systems of straight wires, partly by reason of the above-mentioned considerations, and partly because each of the convolutions of a spiral tends to increase its combined effect.

§ 62. The dynamical induction produced by the action of a current upon a neighboring conductor, is often greatly modified by the induction of the current upon itself, or rather upon the natural electricity of the conductor in which it moves. When the poles of a simple galvanic battery, feebly excited, are connected by means of a short wire, no spark will be obtained; but if a long wire be used for the same purpose, a brilliant spark is produced whenever contact is broken, and the effect is much increased by coiling the wire upon itself. If the wire be doubled, and then coiled into a spiral, with the point of doubling at its centre, the current passes in opposite directions in the adjoining convolutions, and the corresponding inductive actions neutralize each other. And if metallic handles be soldered to the two ends of a ribbon coil (§ 61), an intense shock will be felt at the elbows, whenever the handles are grasped, and a current is suddenly interrupted in its passage

through the coil by breaking contact. These facts, discovered by Prof. Henry, have been fully investigated and shown by him to be effects of a true secondary current in the conductor, caused by the action of the primitive current upon its natural electricity.

Long wire helices, by reason of their great resistance and numerous spires, induce in themselves secondary currents of intensity, which will produce powerful shocks; while ribbon coils develop induced currents of quantity, and give the most brilliant deflagrations. If the length of a coil or helix be increased to such an extent that the resistance becomes too great for its conducting power, then the inductive effects decrease with each additional length, the battery current being constant. Within the limit of ready conduction, however, the effects increase with the length. A certain length, therefore, which varies with the sectional area of the wire or ribbon, and with the quantity and intensity of the current, gives a maximum result.

Large simple batteries, combined with ribbon coils, produce the greatest deflagrating and other effects of quantity; while compound batteries, with very long helices, give the most intense shocks, even if the plates be very small. One of the original experiments of Prof. Henry shows the comparative effects of simple and compound batteries with reference to induced secondary currents in a striking manner; a very small battery, formed of six pieces of copper bell wire, an inch and a half long, and an equal number of pieces of zinc of the same size, combined with the spool of wire five miles in length (§ 61), gave a shock sufficiently intense to be taken by twenty-six persons joining hands. But with the same spool of wire and a simple battery, exposing a zinc surface of one square foot and three-fourths, no shock could be obtained; the galvanometer, however, indicated the passage of a current which was too feeble to induce a secondary current capable of overcoming the resistance of so long a wire.

§ 63. The direction of an induced current in the connecting wire of a battery being opposite to that of the primitive current, the influence it exerts upon the natural electricity of a second and parallel wire is of course adverse, and tends to neutralize the action of the battery current.

Similarly, if a metallic plate, or a coil forming a closed circuit, be interposed between a ribbon coil, acting inductively upon a helix, the shock which would otherwise be produced by a secondary current in the helix is completely neutralized by the adverse action of a current induced in the plate or coil. That this screening effect of a closed circuit is due to a current in the plate, was shown by Prof. Henry in the following manner. An interposed circular plate of lead caused the induction in a helix to disappear; a slip of the metal being then cut out from the circumference to the centre, the plate no longer possessed any screening power, and the shocks obtained were equally intense whether it was interposed or not. That the induction does not take place through the opening in the plate,

was proved by putting a similar metallic disc, cut in the same manner, over the first, in such a position that the opening of one should be opposite to the continuous portion of the other; a pane of glass being also placed between the two metallic plates, to prevent contact and the formation of a closed circuit; with this arrangement shocks of equal intensity were obtained. But the existence of a latent current was rendered evident by attaching the ends of a wire to the two edges of the opening in the circular disc; the current was thus drawn out of the plate, and needles were magnetized by it in a spiral forming part of the connecting wire. Various other ingenious experiments were performed to confirm the conclusions thus established, of which we will only mention one; the metallic plate, instead of being interposed, was placed contiguous to and beyond the helix, and it was found that the same neutralizing effect was produced as under the former circumstances.

§ 64. Although the neutralizing power of closed circuits is so great that secondary currents which give shocks so intense as to paralyze the arms, are rendered incapable of producing perceptible sensations, or of magnetizing steel needles; yet, if the existence and quantity of the secondary current be indicated by means of a galvanometer, no variation will be observed, whether a closed circuit be interposed or not. This singular fact, which at first constituted an apparent discrepancy between the results obtained by Prof. Henry, in this country, and those of Dr. Faraday, in England, who both undertook to investigate the subject, has been shown by the former to be in strict accordance with, and a direct consequence of the wave theory of dynamical induction.

As the secondary current induced at the beginning of a battery current flows only in the direction opposite to that of the primitive or inducing current, and for but a single instant, during which its motion first increases until it has attained a maximum velocity, and then declines gradually to a state of rest, so that it consists of a single reflex wave; it follows, that the corresponding current of the third order, induced in a third parallel conductor by the variations in the flow of the secondary wave, will consist in fact of two waves in opposite directions, each of which, like the secondary wave, will pass first through an increasing, and then through a decreasing series of velocities. And a current of the fourth order will, therefore, consist of four waves, one of the fifth order of eight waves, and so on.

Hence, it is evident, that if the needle of a galvanometer is always deflected through the same number of degrees by a current of the same quantity, whatever may be its velocity,—a fact established experimentally by Dr. Faraday,—then the current induced in an interposed metallic plate or circuit should exercise no neutralizing influence upon the inductive action of two adjacent spirals, as indicated by a galvanometer; provided the two waves which constitute the tertiary current produced by the adverse secondary current in the inter-

posed circuit both take place during the time of a single vibration of the needle. For, by reason of the opposite directions and equal quantities of these tertiary waves, they compensate each other, and the quantity of the current induced in the second spiral and indicated by the deflection of the needle, therefore, remains unchanged.

But, as the phenomena of shocks and of the magnetization of steel needles require for their production currents of intensity, or of sufficient velocity to overcome resistance opposed to their motion, they are affected by the adverse inductive actions of the primitive current and of the portion of the secondary wave of increasing velocity, which tend to neutralize each other.

§ 65. The shocks given by a helix are rendered much more intense by placing a bundle of iron wires in the axis of the helix, by reason of the reaction of the magnetism developed in the iron. The theoretical explanation of which fact will be obvious, when we shall have discussed the subject of magneto-electricity.

§ 66. The various galvanic coil machines which have been of late years invented, and employed for amusement or for medical purposes, all depend upon and are easily explained by the above-mentioned principles of dynamical induction. They differ chiefly in the means employed for making and breaking contact, which is done either by mechanical or electro-magnetic contrivances, some of which are very ingenious.

One of the simplest and readiest means of changing the intensity of the shock produced by an induced current, is to vary the distance between the conductors; in this manner any desired degree of diminution may be attained, and electrical currents may be safely employed for the medical treatment of delicate cases.

§ 67. It is perhaps worthy of remark, that, though interposed conductors exercise a screening power, non-conductors are entirely destitute of any such influence. This fact is shown in an amusing manner, by placing a ribbon coil, wound in the shape of a ring, upon one side of a partition wall between two rooms, and causing a person on the other side to grasp the handles of a helix of similar form, and move it towards the spot opposite the coil; a shock will then be received by him, without any visible cause; and if the coil and ribbon, as well as the battery, be very large, this effect may be produced even at the distance of several feet.

§ 68. *Action of Currents on Currents; or Electro-dynamical Attraction and Repulsion.* We owe our knowledge of this interesting subject almost entirely to the ingenious and fertile investigations of M. Ampère. It constitutes by far the most important portion of Electro-dynamics, by reason of the fact that it is the bond of connection between electricity and magnetism, and the foundation of the mathematical theory which embraces and accounts for all the known phenomena of electro-magnetism. These phenomena, like those of ordinary electricity, are so numerous, and susceptible of such infinitely varied modifications

and combinations, that for reasons precisely similar to those stated in (§ 6), a theory is not only useful but necessary.

The first discovery in Electro-dynamics, which served to draw particular attention to the subject, was made in 1820 by Prof. Oersted of Copenhagen, who found that a magnetic needle acted upon by a galvanic current assumes a position at right-angles to the direction of the current. Other new and important facts were promptly discovered by Ampère, Arago, Davy, Faraday and others; and all the observed phenomena were satisfactorily referred by Ampère to the laws which govern the mutual action of electrical currents, by means of the ingenious hypothesis that magnetism consists in electrical currents revolving around the molecules of a magnet, in planes perpendicular to its axis.

In the limits of an article so brief as this, we cannot enumerate in detail the successive steps by which this portion of electrical science was rapidly advanced; nor undertake to describe the apparatus invented for the purpose of illustration, or even much of that employed by Ampère and others in their original researches. We therefore refer the reader for such information to the more extended treatises on the subject, with the remark that the books in the English language on this branch of physics abound in descriptions of apparatus and isolated experiments, but are, in our opinion, generally deficient in theoretical exposition.

§ 69. The laws of electro-dynamical attraction and repulsion, experimentally established by M. Ampère and which serve to explain all the known phenomena, may be succinctly stated in a few general propositions.

Prop. 1. Parallel currents flowing in the same direction attract each other; and they mutually repel, when their directions are opposite.

Prop. 2. Two currents attract each other when they both flow towards or from a point, or the line of shortest distance between them if they are not in the same plane; and they repel each other, if one approaches and the other recedes from it.

Prop. 3. The forces vary in intensity in the inverse ratio of the square of the distance. And the action of a current flowing in a given direction is, in all cases, equal and contrary to that which it exerts when it passes in the opposite direction, the current acted upon and the distance remaining constant.

Prop. 4. The attraction or repulsion exerted by a current passing through a tortuous conductor, however numerous its flexures, is exactly equal to that which is produced by the same current when it flows in a straight line between the same points.

§ 70. The last proposition is one of great importance and value, for it proves that the action of an elementary portion of a current is equivalent to that of any polygonal system of infinitesimal currents which may connect its extremities; and, therefore, that we may substitute for such an element, ds , the corresponding elements dx , dy , dz , its projections on the axes of co-ordinates.

Hence, we may express analytically the actions of the elementary portions of currents, situated in any manner in space, and by integration determine those of the currents themselves.

For this purpose, let ds, ds' be the infinitely small portions of any two currents, exerting upon each other forces, the intensities of which, at the unit of distance, are expressed by i, i' ; for greater simplicity, let these elements be referred to rectangular axes, the line, r , connecting their middle points being assumed as the axis of x , and the plane of x, y , being that formed by the element ds , with the same line or axis. Denote also, by α, β , the angles formed respectively by ds, ds' , with r ; and by γ , the angle which the plane r, ds makes with the plane r, ds' .

Substituting for ds, ds' , their projections dx, dy and dx', dy', dz' , we have two parallel currents, dy, dy' , the action of which upon each other (Prop. 1) is expressed by

$$d\phi = \frac{i, i'}{r^n} \cdot dy \cdot dy'; \quad (A)$$

and also, two other infinitesimal currents, dx, dx' , situated in the same straight line, r , and which act upon each other (Prop. 2) with a force denoted by

$$d\psi = k \cdot \frac{i i'}{r^n} \cdot dx \cdot dx'; \quad (B)$$

in which formulas k is an unknown coefficient of position, expressing the ratio of the action of dx, dx' upon each other, to that which they would exert if parallel; and the factor $\frac{1}{r^n}$ is employed to denote the variation of the forces with the distance r , in some unknown ratio to be determined by the value of n .

It is evident, by virtue of Prop. 2, and the symmetry of their relative actions, that all the forces into which we have resolved $ids, i'ds'$, except those of (A) and (B), will be in equilibrium. Hence, the total action of ds, ds' , upon each other is expressed by the equation

$$df = \frac{i i'}{r^n} (dy \cdot dy' + k dx \cdot dx');$$

or, substituting for dx, dy , their values $ds \cdot \cos \alpha, ds \cdot \sin \alpha$; and for dx', dy' , their values $ds' \cdot \cos \beta, ds' \cdot \sin \beta \cos \gamma$, we have the general formula

$$df = \frac{i i' \cdot ds \cdot ds'}{r^n} (\sin \alpha \sin \beta \cos \gamma + k \cos \alpha \cos \beta); \quad (C)$$

by the integration of which, the action of any current upon another may be determined, when the values of the unknown quantities k and n have once been ascertained.

By applying this formula, (C), to two particular cases in which the forces were shown by experiment to produce equilibrium, MM. Ampère and Savary obtained, for the determination of the values of k and n , two equations of condition, one of which was of the second degree, and therefore susceptible of two solutions. A third experiment served, however, to decide between these different solutions, and to give the values $n = 2, k = -\frac{1}{2}$, as those of the unknown quantities.

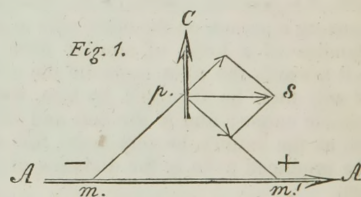
§ 71. The value of $n = 2$ evidently proves that the forces exerted by currents upon each other, like the physical forces of Nature generally, are subject to the law of variation inversely as the square of the distance; and thus the first clause of Prop. 3 was established by M. Ampère. That electro-magnetic forces, attributed by Ampère to hypothetical currents (§ 68), are governed by the same general law, was experimentally shown by MM. Biot and Savart, by means of the torsion balance of Coulomb.

§ 72. The negative value obtained for the coefficient k indicates, that two currents flowing in the same direction and situated in the same right line, or two portions of a single rectilinear current, repel each other. This conclusion, deduced mathematically from the above general formula, (C), was put to the test of direct experiment and confirmed by M. Ampère, by means of a simple and ingenious contrivance composed of a wire bent U-shaped, and delicately floated by its two legs in two separate channels of mercury similarly connected with the opposite poles of a battery; repulsion was shown by the receding motion of this wire along the mercurial channels.

The same formula was applied by MM. Ampère, Savary and others to numerous experiments, or cases for which integration could be readily performed, and shown in all instances to give perfectly accordant results. It is therefore evident, that our knowledge of the laws of electro-dynamical attraction and repulsion is coextensive with our power of mathematical application and deduction; and also, that the fundamental facts of (§ 69), are established by means of a severe and sufficiently extended investigation.

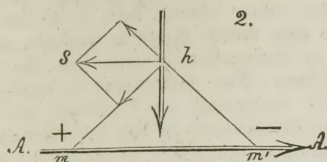
§ 73. We shall now deduce from the propositions of (§ 69), the effects of the mutual action of currents in certain cases of frequent occurrence, for the illustration of which much of the apparatus usually constructed by the instrument-makers is designed.

Case 1. When an indefinite current AA (Fig. 1), acts upon a terminated current C ,



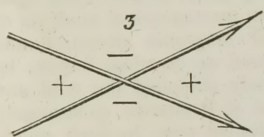
flowing at right-angles to it, an element p of the current C is under the influence of forces exerted by any elements, m, m' , of the current AA symmetrically situated, and acting with equal intensities. If the current AA flows to the right, and C upwards (Fig. 1), then m acts repulsively or minus, and m' attractively or plus (§ 69, Prop. 2); and from the theorem of the parallelogram of forces, it follows that C will tend to move to the right with the force ps represented by the diagonal of the parallelogram.

But if C flows downwards (fig. 2), then the forces of m, m' , are reversed, and C tends to move with equal force to the left.



This case combined with the hypothesis of Ampère (§ 68), furnishes the theory of the fact discovered by Faraday, that a movable current will revolve around a magnet; and conversely, action and reaction being equal, a movable magnet will revolve around a fixed current. Also, of Ampère's rotating cylinders and various other illustrative electro-magnetic apparatus.

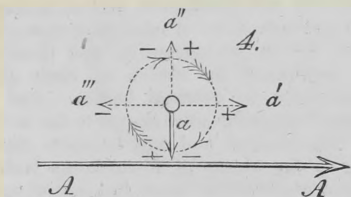
Case 2. When two movable currents cross



or form an angle with each other, as shown in fig. 3, it is evident that the attractive, plus, forces combine with the repulsive, minus, forces, to cause the currents to turn and assume parallel positions.

The theoretical explanation of the fact discovered by Oersted (§ 68), as well as of the galvanometer and other instruments, depends upon this case.

Case 3. When an indefinite rectilineal current, AA , acts upon a terminated and suspended current, a , the latter will revolve. This will appear evident (Props. 1, 2, § 69) upon inspection of fig. 4; the attractive and repul-

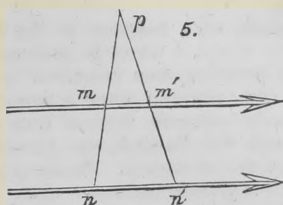


sive forces, for the different quadrants, $a, a', a'',$ and a''' , being indicated by the signs plus and minus, and shown to produce continued rotation in the direction of the two dotted arrows.

Hence, also, an indefinite current produces rotation, when it acts upon a system of convergent or divergent radial currents, such as would flow between the centre and circumference of a circular disc, or through a fluid conductor contained in a metallic vessel, to or from the end of a wire immersed in the fluid. We may thus explain vortices produced by electro-magnetical action in mercury, and many other instances of rotation.

§ 74. It should be remembered, in all mathematical reasonings upon the action of currents, that the law of variation inversely as the square of the distance is established by the value $n = 2$, only for the mutual action of infinitesimal or elementary currents (§ 70); for if an element act upon an indefinite rectilineal current, it will exert a force inversely

proportional to the distance, and not to its square. This is evident from fig. 5, in which



p represents an element; $m m'$, a unit of length of an indefinite current, at the unit of distance from p ; and $n n'$ a portion of the same current removed to any distance, d ; then $n n' = d (m m')$; and the action of p upon each of the elements of $n n'$ being inversely as the square of d , we have for the total action

$$f = \frac{p \cdot (n n')}{d^2} = p \cdot \frac{d \cdot (m m')}{d^2} = \frac{p (m m')}{d};$$

hence,

$$f : p \cdot (m m') :: 1 : d;$$

or the resultants of the forces are inversely proportional to the distances.

In like manner, it may readily be shown that the action of an element upon similar surfaces is equal at all distances; the forces varying inversely, and the surfaces directly, as the squares of the distances.

§ 75. We may here observe that, by supposing the opposite sides of electrical currents to possess opposite properties, all cases of attraction and repulsion may readily be rendered evident upon mere inspection. Thus, in the diagrams, we have placed the dark line, or shaded side, *always to the right of the current*; and the action in each case may be determined by the general rule, that *like sides repel*, and *unlike attract*. This mode of conceiving of the mutual action of electrical currents, is often extremely convenient; and it may greatly aid those who are not familiar with mathematical methods of reasoning.

4. Magneto-Electricity.

§ 76. Under this title we shall discuss not only the electrical phenomena to which it has been limited by some writers, but also the subjects of magnetism and electro-magnetism.

The term *electro-magnetism* is usually applied by English writers to the magnetic and dynamical effects caused by electrical currents; and, conversely, *magneto-electricity* to the electrical phenomena produced by magnetism. M. Ampère employs the word *electro-dynamics* to embrace all magnetic, electro-magnetic, and magneto-electrical phenomena, as well as the action of electrical currents on each other (§§ 68—74); but it seems to us preferable to give to that term a more extended signification (§ 7), and to make use of *magneto-electricity* as a suitable name for the classification of all facts relative to magnetism, or to the connection and mutual action of electricity and magnetism.

§ 77. It was known to the ancients that the *loadstone* possessed the power of attracting iron; but their speculations with reference to this property were metaphysical and fruitless.

This mineral, an oxide of iron, was called by the Greeks *μαγνης*, from which the word *magnet* is derived.

The *polarity* of a magnet, or the directive property by which it tends to assume a north and south position, was unknown in Europe until the 12th century, when a knowledge of the mariner's compass, derived from the Chinese through the Tartars, was brought from the East by the crusaders. Nothing, perhaps, has exerted a greater influence upon the progress and history of the world than the use of that simple instrument; guided by it, Columbus pursued his course to a new hemisphere, and navigators, no longer compelled to depend only upon familiar stars, or keep within reach of well-known shores, have visited every portion of the globe, rendering commerce coextensive with the habitable world.

§ 78. No attempt was made to investigate the phenomena of magnetism experimentally, before the time of Dr. Gilbert, who published his researches in a treatise entitled *De Magnete*, A. D. 1600; this work, to which we have already had occasion to refer (§ 1), contains nearly every important fact known until 1759, when Æpinus of St. Petersburg brought forward, in his *Tentamen Theoriæ Electricitatis et Magnetismi*, a mathematical theory which seemed to connect magnetic phenomena; as that of Franklin, which he adopted and amended (§ 5), does those of electricity.

§ 79. The general phenomena of magnetism and electricity are very analogous; thus, similar and dissimilar ends, or *poles*, of magnets mutually repel and attract; bodies are rendered magnetic by *induction*; and the sensible distribution of magnetism, like that of electricity, is superficial. But magnetism is incapable of *transference*, since a magnet becomes stronger, and therefore gains instead of losing power, when used to impart magnetism to another body. Ordinary magnetism, also, can be readily developed only in a few metals; and it is permanent in steel, but transitory in soft iron.

§ 80. *Theory of Æpinus.* To connect and render the phenomena of magnetism susceptible of mathematical investigation, Æpinus ascribed them to the action of a subtile hypothetical fluid, the properties of which he assumed to be as follows:

1. The particles of the magnetic fluid mutually repel each other, and attract those of iron.
2. This fluid exists in, and is incapable of passing out of ferruginous bodies, though it is free to move within them. To this internal motion steel opposes great resistance, but soft iron comparatively little.
3. The particles of absolute iron, or that deprived of its natural portion of the magnetic fluid, repel each other.

This theory accounted satisfactorily for all the phenomena, with one exception,—when a magnet is broken, the fragments are all found to be magnets, exactly similar in every respect to the original magnet and to each other. But, according to the theory of Æpinus, the state of a magnetized body is assumed to be one of tension analogous to that of a body

electrified inductively (§ 24); one end containing more than its natural share of the hypothetical fluid, or being magnetized *plus*, and the other having less, or being *minus*. Hence this theory failed to include, and was even in contradiction with, the above-mentioned fact. The defect may be easily remedied by supposing, as Coulomb afterwards did, the disturbance of the hypothetical fluid, or tension, to take place molecularly; and the theory of Æpinus will then explain all simple magnetic phenomena.

§ 81. It should be remarked, that the merit of a physical theory does not consist so much in its being a true representation of the laws of Nature, as in its serving to guide investigation in the path of discovery, and especially by means of mathematical deduction. The claims of Æpinus to our consideration are not, therefore, lessened by the failing case of his theory; for they are based upon his clear and exact mathematical analysis of the phenomena of magnetic attraction and repulsion, considered as physical forces; by which he completely dispelled the wild and vague speculations of Descartes, so strangely entertained and adopted even by such minds as that of Euler, long after they were brought forth.

§ 82. *Discoveries and Theory of Coulomb.* The next important step in the progress of magnetism was made by Coulomb, who was enabled, by means of his balance of torsion, to measure exactly the intensity of magnetic forces, and thus to prove that they vary inversely as the square of the distance.

He also modified and improved the theory of Æpinus, by supposing a magnet to consist of magnetic molecules or *elements*, having each a north and south pole, and so arranged that the opposite poles of internal consecutive elements are in juxtaposition, and therefore tend to neutralize the action of each other with reference to external bodies. And he ascribed all magnetic phenomena to the action of two hypothetical and imponderable fluids, existing in the atoms of ferruginous bodies, and called respectively *boreal* and *austral* magnetism; like particles of which mutually repel, while unlike particles attract each other.

The development of magnetism, according to this theory, consists in the inductive separation of the two fluids in the molecules or magnetic elements; and iron and steel are supposed to exert very different degrees of resistance to this internal molecular motion of the fluids, as well as to their return from the polar or separated state to that of combination and perfect neutralization.

This theory discussed and applied mathematically, first by Coulomb and subsequently by Poisson, was found to be in strict accordance with, and to account satisfactorily for, all observed magnetic phenomena, until the electro-magnetic discoveries of Oersted, Ampère, Faraday and others, required for their connection and explanation some new hypothesis or physical conception, by which magnetism should be ascribed to an electro-dynamical cause. Such an hypothesis constitutes the basis of the ingenious and beautiful theory

of Ampère, already briefly alluded to in (§ 68), and of which we shall now, for reasons stated in (§ 6), endeavor to give a full exposition.

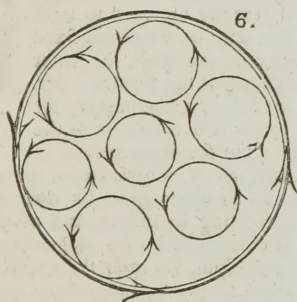
§ 83. *Theory of Ampère.* (1.) All the phenomena of magnetism are due to the action of constant electrical currents revolving around every magnetic element at right-angles to the axis passing through its poles.

(2.) These electrical currents are governed by the laws of electro-dynamical attraction and repulsion (§§ 68—74); and they possess the power of inducing similar currents in ferruginous and other conducting bodies.

§ 84. To classify and discuss the various phenomena of magneto-electricity, we shall treat of them under the following heads:—1. Distribution; 2. Attraction and Repulsion; 3. Induction; 4. Terrestrial Magnetism.

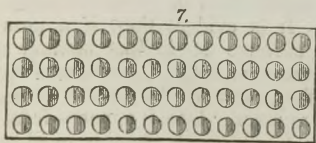
§ 85. *Magnetic Distribution.* We have already seen (§ 80) that it is necessary to suppose magnetism to be a molecular property; but it may be shown, by the theory of Ampère, or by that of Coulomb, as well as by experiment, that the external or sensible action of a magnet is produced by the superficial elements. And it follows, therefore, that hollow magnetic bodies exert as much force as those of equal size and similar figure which are solid,—the metal and degree of magnetization of both being the same.

If, as the theory of Ampère assumes, electrical currents revolve around the particles of a magnet, as represented in transverse section in fig. 6; it is then evident, that the



opposite forces exerted by adjacent portions of the internal elementary currents will neutralize each other, and that the resultant of each sectional system will, therefore, be equivalent to that of a large superficial current circulating around the whole. Hence, in discussing the action of magnets, we may generally disregard the molecular forces, and consider only those which would be exerted by external circumferential currents substituted for them.

An inspection of the annexed diagram (Fig. 7), representing in longitudinal section



the hypothetical state of a magnet according to the theory of Coulomb, will serve to show, that it may readily be inferred from that theory,

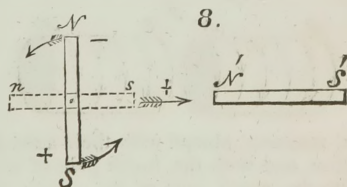
that the external action of all the elements should be the same as that of a superficial magnetic stratum. And this conclusion Poisson has demonstrated rigorously, as a consequence of the theory.

In the course of a valuable series of experiments on magnetic attraction, Mr. Barlow found, that a solid 10-inch ball of iron, used for proving mortars, and weighing 128 lbs., produced *exactly the same* deviations of a magnetic needle in various positions, as those he obtained with a 10-inch shell, weighing 96 lbs., or having only three-fourths of the mass of the former. This fact he tested and extended by employing shells of different thickness; and he thus proved "that the power of magnetic attraction resides wholly on the surface, and is independent of the mass."

§ 86. *Attraction and Repulsion.* That the forces which magnets exert vary inversely as the square of the distance, was proved by Coulomb in two different ways: first by measuring directly the torsion required to resist the deflecting action of a magnet upon a suspended needle, at successive distances; and, secondly, by vibrating the needle, thus attracted or repelled, and observing the number of oscillations which take place in a given time. These methods are similar to those employed for measuring electrical forces (§§ 18—22) and the method of oscillations (§ 18) is also that which was used by MM. Biot and Savart (§ 71), to show that electro-magnetic forces obey the same general law.

§ 87. Previously to the labors of Coulomb, the only mode of determining the power of a magnet, was by trying what amount of weight it could lift: a rude method, but one which may frequently be useful in experimental researches.

§ 88. When a fixed magnet acts upon another which is free to move in any direction, it tends to produce two distinct kinds of motion in the latter: one *directive*, by which the movable magnet is deflected, and the other *translative*, which would cause the two magnets to come together. This is evident from the annexed diagram (fig. 8), in which the arrows



and signs + and —, indicate the attractive and repulsive forces between the poles S and N of the movable magnet, and the pole N' of the fixed magnet. By the sum of which forces the former tends to turn about its middle point, as a centre, and to assume the position n, s , with its pole S directed towards N' . In this position, the movable magnet is still attracted with a translative force equal to the difference of the forces corresponding to the distances of the points s and n from N' . For the sake of simplicity, we have considered only the forces exerted by the pole N' of the fixed

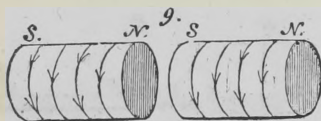
magnet, but it is evident that its other pole S' will have an opposite action, the intensity of which will be to that of N' in the inverse ratio of the squares of their respective distances from the movable magnet; and the whole action of the magnet $N'S'$ will, therefore, be equal to the difference of the actions of its two poles.

When the ratio of the distance between two magnets to the length of the movable magnet is very great, it is evident that the translative force will be inappreciable, while the directive force will still act energetically. The one being the difference, the other the sum of forces of nearly equal intensity.

§ 89. The forces of magnetism operate through different media with equal intensity; or alike in vacuo and through solid, liquid and gaseous substances. Hence, since they also vary with the distance according to a well-known law (§ 86), we may apply magnetism to such purposes as the determination of the thickness of a wall or other solid structure, which cannot readily be measured by simpler means.

§ 90. To deduce from Ampère's theory the phenomena of magnetic attraction and repulsion, it becomes necessary first to ascertain the direction which the laws of electro-dynamical action (§ 69) require us to assume, to be that of the currents supposed to revolve around the axes of magnets. And it has been found that to render the theory accordant with observed facts, the motion of the hypothetical currents must be *contrary* to the apparent daily motion of the sun, or to that of the hands of a watch, when the north pole of the magnet is elevated.

§ 91. The simplest method of applying this theory, and of tracing its consequences under all possible combinations of relative position and distance between any number of magnets, is to make a number of models of wood or paper, representing hypothetical magnets, and to employ them, with the laws of the action of currents on currents (Cases 1—3, § 73), to deduce the actions which should take place. Thus, for example, we have represented, in fig. 9, two such models or hypo-



thetical magnets, placed with their axes in the same line, and with the north pole of one adjacent to the south pole of the other; in this position the currents flow in the same direction, and therefore the two magnets attract each other (§ 69); but, if the position of either of the models were reversed, like poles would be placed together, the currents would flow in opposite directions, and repulsion should ensue.

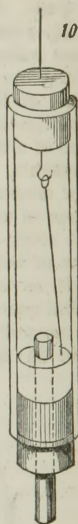
Similarly, it may be shown in every instance that the theory of Ampère furnishes a ready explanation of the action of magnets on each other.

§ 92. With equal simplicity, all the effects produced by the mutual action of electrical currents and magnets, flow from the same

theory, as consequences of the established principles of electro-dynamical attraction and repulsion (§ 69). To illustrate this, we shall apply the theory to some of the most important and familiar facts.

§ 93. The fact of Oersted (§ 68),—that a magnet assumes a polar position transverse to that of an electrical current, or tangential to circles described about the latter as an axis, is a simple instance of (§ 73, Case 2), or of the tendency of currents to assume parallel and similar directions.

§ 94. The mutual rotation of currents and magnets about each other as axes, discovered by Faraday, is explained by (§ 73, Case 1). The first and simplest contrivance of that distinguished philosopher, for exhibiting the motion of a current around a magnet, consists of a glass tube, fig. 10, four or five inches long, and about half an inch in diameter, the two ends of which are closed by corks; a small magnet passes through the bottom cork into the tube, the space between the magnet and the tube being partly filled with mercury; and a fine platinum wire is freely suspended by means of a hook of the same metal from the upper cork. When a current passes through the movable wire, it revolves rapidly around the magnet, and the direction of its motion changes whenever that of the current is reversed. Also, since action and reaction are always equal and directly opposed to each other, if the wire be rendered fixed and the magnet movable, the latter will revolve about the former. Mr. Faraday invented arrangements for showing these two rotations at the same time; but for descriptions of them, as well as of contrivances for causing a magnet to revolve upon its own axis, of Ampère's rotating cylinders, and of other ingenious philosophical toys dependent upon the same principle, we refer the reader to any of the treatises on electro-magnetical apparatus and experiments.

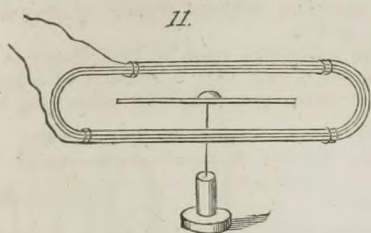


§ 95. The rotary motion of a movable current about a magnet is easily and beautifully shown by means of mercury. If the conducting wire from one of the poles of a battery terminate in a circular copper ring, immersed in a shallow basin of mercury, and the end of the wire from the other pole be dipped into the mercury at a point near the centre of the ring; then the convergent or divergent currents between the ring and the centre will give rise to rapid rotation of the mercury, whenever the pole of a magnet is brought near to that centre, either above or below the basin.

§ 96. It is evident that, if a number of similar currents act in like manner upon a given current or magnet, the sum of the forces which they exert will be directly proportional to their number. Also, it appears from (§ 69), that any two currents flowing in opposite directions should act alike upon a magnet placed between them.

Upon these two principles the "electro-mag-

netic multiplier," or galvanometer, of Schweigger is constructed. A long wire is coiled upon itself in such a manner as to form a quadrilateral opening, in which a delicate magnetic needle moves with ease upon a sharp pivot (fig. 11); each spire of the wire pro-

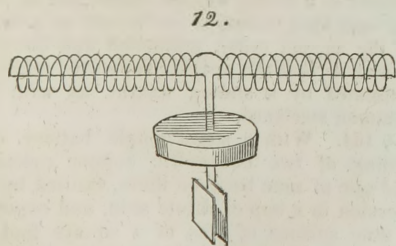


duces an effect equal to that of two single currents, and the total action is equal to the sum of the actions of all the spires. The spires should be insulated by wrapping them with silk or cotton yarn, to prevent the passage of the current from one spire to another.

This beautiful contrivance has been greatly improved, and made not only more delicate, but also exact in its indications of the intensities of the electro-magnetic forces, by suspending the needle with a single silk fibre, so as to constitute a balance of torsion. And it has been rendered independent of the directive tendency of the earth's magnetism, by employing two magnets connected firmly together, with their similar poles in opposite directions, and suspended in such a manner that one shall be above and the other below the superior portion of the quadrilateral coil. Such an arrangement is usually called an *astatic* needle; and it is often very useful and convenient for researches, in which it is requisite to eliminate the effects of terrestrial action.

§ 97. If a copper wire be bent in the form of a helix, like the thread of a screw, by winding it closely upon any cylindrical body, and then removing the latter from the interior of the spires; it follows, from the theory of Ampère, that such a helix, which he calls an *electro-dynamical cylinder*, will exhibit all the properties of an ordinary magnet of similar size and shape, whenever an electrical current is made to pass through it. This consequence of the theory has been fully verified by experiment, so that electro-dynamical cylinders may in all cases be substituted for magnets, or conversely, magnets for cylinders, with similar results.

The annexed diagram (fig. 12) represents a



convenient and simple mode of constructing

an electro-dynamical cylinder, in which the extremities of the wire of the helix pass down through a large cork, and are soldered one to the zinc, the other to the copper plate of a galvanic pair. This little apparatus is rendered active by floating it upon acidulated water, in a vessel of sufficient size to avoid adhesion; and it readily exhibits the properties of a magnet, assuming a north and south position, and having its poles repelled by like, and attracted by unlike poles of ordinary magnets.

The only difference between the action of such cylinders and of magnets, is in the intensity of their respective actions. And this result should be anticipated, as a consequence of the theory; the number of the hypothetical currents in a magnet being supposed to be infinitely great, and that of the currents of a helix being limited by the number of its spires.

Another and a simpler toy for illustrating the same truth, was invented by M. De la Rive; in it the wire is coiled in the form of a ring, and its two ends pass down through a cork to be soldered to a galvanic pair of plates, as in the arrangement described above. Such a ring acts exactly like an equal number of spires of an electro-dynamical cylinder.

It is often convenient, for experiments, to have the convolutions of a spiral conductor situated concentrically and in a single plane; and such an arrangement evidently acts with the combined effect of all its spires.

§ 98. The established principles of electro-dynamical attraction and repulsion, combined with the theory of Ampère, not only furnish a ready explanation of every electro-magnetic machine which has been or may be invented, but also enable any one to foresee the result of new combinations, and therefore to contrive without difficulty an unlimited number of arrangements for the purposes of illustration. When the nature and laws of physical forces are once determined, it is the office of mere mechanical ingenuity to apply those forces; but little credit can therefore be any longer claimed for the invention of an electro-dynamical toy.

§ 99. *Magneto-electrical Induction.* When a magnet is brought near to, or in contact with soft iron, the latter acquires all the properties of a magnet; but it does not retain them, if removed from the exciting influence of the magnet.

This action is very analogous to the inductive disturbance of the electricity of bodies, discussed in (§§ 24—27). The analogy is, however, imperfect; for electricity moves freely in conductors, and even passes readily from one body to another, when the distance between them is not too great; while magnetism seems to be molecular, and incapable of transference even from particle to particle of the same mass. Hence, magnetic development is a purely inductive result, and is greatest between two bodies when they are in contact. Hence, also, it is impossible to magnetize a body with either a northern or southern polarity alone; and two halves of a broken

magnet are not found to be in opposite states, but similar to each other and to the original magnet.

§ 100. The phenomena of ordinary magnetic induction are explained by the theory of Coulomb, as those of electrical induction are by the theory of Dufay; but the theory of *Æpinus*, as we have already seen (§ 80), is insufficient to account for them satisfactorily, without an additional postulate.

§ 101. That *Ampère's* theory may embrace the facts stated above (§ 99), as well as other inductive effects, it is evidently requisite that electrical currents should possess the power of inducing currents similar to themselves, and also of developing magnetism in ferruginous bodies.

Under the head of electro-dynamical induction (§§ 58—64), we have already discussed many facts relative to the induction of currents by currents; and that currents are also induced by magnetism (theoretically by the hypothetical currents of *Ampère*), will be fully set forth in a subsequent portion of this article, (see § 115).

In the month of July, 1820, *Oersted* made known his celebrated discovery (§ 68), and in the succeeding September, *Arago* communicated to the Academy of Sciences at Paris, the second electro-magnetic discovery, that a galvanic current possesses the power of rendering iron or steel magnetic.

It therefore appears that the power of electrical currents to induce other currents and develop magnetism, required for the verification of the theory of *Ampère*, is found by experiment to be a physical fact.

§ 102. *Induction of Magnetism by Electricity.* To the important discovery of magnetic induction by electrical currents, *M. Arago* was led, by observing that iron filings are attracted by the conducting wire of a galvanic battery. That this property is magnetic, and not simply electrical, was shown by the fact that the filings of other metals are not similarly attracted, and also by permanently magnetizing steel needles enveloped in electro-dynamical helices. And that the phenomena is one of induction, was proved by the fact that the filings and needles acquire magnetic properties without contact with, and even at a distance from, the conducting wire.

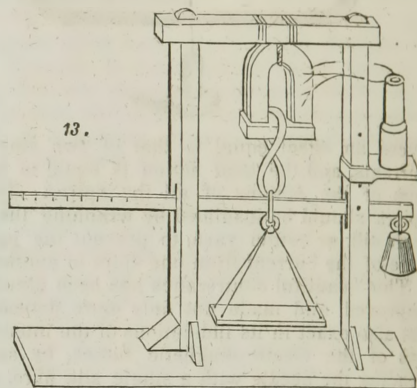
Nearly at the same time that *M. Arago* was engaged in making these beautiful and valuable experiments in France, *Sir H. Davy* was occupied with similar investigations in England; which resulted in the independent discovery of the same facts by each of those distinguished philosophers.

Mr. Sturgeon substituted for the steel needles used by *Arago* and *Davy*, pieces of soft iron wire wrapped in helices of copper, and found that they were rendered intensely magnetic.

§ 103. Our knowledge of electro-magnetic induction was next extended by the researches of *Prof. Henry*, who found that the principle of the galvanic multiplier (§ 96) may be applied to the development of great magnetic power in soft iron, by a small galvanic bat-

tery; and employed it for the purpose of studying the inductive action of electrical currents upon considerable masses of iron, and of investigating the relative power of currents of different quantity and intensity, as well as of the same current when transmitted through insulated conducting helices of various lengths, and opposing different degrees of resistance to its motion.

The apparatus used by *Prof. Henry* is represented in (fig. 13); it consists of a bar of iron, 2 inches square and 20 inches long, bent



in the form of the letter U, or of a horse shoe $9\frac{1}{2}$ inches high, and weighing 21 lbs. avoirdupois; a piece of iron from the same bar, weighing 7 lbs., was filed flat on one surface for an *armature* or lifter; and the extremities of the legs of the horse-shoe were truly ground to the surface of the armature. Around the horse-shoe 540 feet of copper wire, well covered with waxed thread to secure insulation, were wound in nine coils of 60 feet each; these coils were not wrapped continuously around the whole length of the bar, but each strand occupied about two inches, and was wound several times backward and forward over itself; the several ends of the wires were left projecting and numbered, so that the first and last of each strand could be readily distinguished. In this manner a large experimental magnet was formed, with which several combinations of wire could be made by merely uniting the different projecting ends; thus, if the last end of the first wire be soldered to the first end of the second, and so on through all the series, the whole will constitute a continuous coil of one long wire; and by soldering different ends, a double coil of half the length, or a triple coil of one-third the length, &c., could be readily formed. The horse-shoe was suspended in a strong wooden frame, and an iron bar was fixed below, so as to act as a lever of the second order, graduated and counterpoised, so that the weights supported might be estimated by a sliding weight, as with the common steelyard.

§ 104. With a small single battery, consisting of two concentric copper cylinders and one of zinc between them, excited by immersion in a cup of dilute acid, and exposing a zinc surface of $\frac{2}{3}$ ths of a square foot, the following results were obtained:—

No. of wires soldered to the battery.	Weight supported in lbs. avoirdupois.
1. Each wire in succession.....	7
2. One on each side of the arch ...	145
2. One from the end of each leg...	200
3. One from each leg, and the other from the arch.....	300
4. Two from each extremity.....	507
6. Three on each side.....	570
9. All the wires attached	650
9. All the wires soldered to a battery exposing one square foot of zinc surface.....	750
9. All the wires attached to a pair of plates exactly one inch square	85

From the above experiments, it is evident that a very small simple battery is capable of producing great magnetic effects, if the spires of the inducing helix are numerous, and the resistance to the passage of the current is not very great.

§ 105. The effect of varying the lengths of the conducting wires and the intensity of the current, was satisfactorily shown by the following experiments. Six wires, each 30 feet long, attached to the small cylindrical battery described above, caused the horse-shoe bar to lift 375 lbs.; and when the same wires were united so as to form three coils of sixty feet, it supported 290 lbs. Hence it appears that, with a simple galvanic battery, six short wires are more powerful than three of double the length.

The two wires which had sustained 200 lbs., when separated, being united so as to form a single coil of 120 feet, lifted only 60 lbs. But when a small compound battery of two elements, exposing exactly the same zinc surface as the single battery used in the last experiment, was substituted for it, the weight lifted was 110 lbs., or nearly double.

Also, a small horse-shoe, $\frac{1}{4}$ of an inch in diameter, wound with 8 feet of copper wire, when attached directly to a simple battery with a zinc plate 4 inches by 7, surrounded by copper, lifted $4\frac{1}{2}$ lbs.; but when the current passed through a copper wire 1060 feet long and 0.045 of an inch in diameter, it supported only half an ounce; through 530 feet, or half of the same wire, it lifted 2 oz. The whole length of the wire being then attached to a small compound battery on Mr. Cruickshank's plan, containing 25 double plates, and presenting exactly the same extent of zinc surface to the action of the acid as the simple battery used in the last experiments, the weight lifted was 8 oz.; and when the intervening wire was removed and the trough attached directly to the ends of the wire around the horse-shoe, it lifted only 7 oz.

Hence Prof. Henry concluded, "that the magnetic action of a compound battery is at least not diminished by passing through a long wire," a fact "directly applicable to Mr. Barlow's project of forming an electro-magnetic telegraph;" which has since been so successfully accomplished by Prof. Morse (§ 34), by means of the electro-magnets of Henry, combined with simple and ingenious mechanical arrangements.

From these experiments, Prof. Henry also inferred, that "we may either use one long wire or several shorter ones, as the circumstances of the case may require; in the first case, our galvanic combination must consist of a number of plates, so as to give projectile force; in the second, it must be formed of a single pair."

§ 106. The effect of increasing the quantity of the battery current is in part shown by some of the above-mentioned experiments (§ 104), from which it appears that 85, 650, and 750 lbs. are the weights supported by the same horse-shoe, when similarly attached to batteries exposing respectively zinc surfaces of 2 sq. inches, $\frac{2}{3}$ ths of a sq. foot, and 1 sq. foot. But when the size of the battery was still further increased, no greater effect was produced; and a calorimeter containing 28 plates of copper and zinc, each 8 inches square, did not indeed lift as much as the smaller battery; so that 750 lbs. was apparently the maximum magnetic power which could be developed in the horse-shoe.

§ 107. A series of experiments was separately instituted by Dr. Ten Eyck, to produce a maximum development of magnetism in a small quantity of soft iron. And he succeeded in causing a horse-shoe of round iron slightly flattened, 1 inch long and 0.06 of an inch in diameter, weighing 6 grains and wound with 3 feet of brass wire, to lift 5 oz. 5 dwt. 4 grs., or 420 times its own weight. The strongest magnet described, appears to be one which was worn in a ring by Sir I. Newton, which lifted nearly 250 times its own weight. Hence, a much more intense degree of magnetism can be developed in soft iron by an electrical current, than in steel by the usual methods of making magnets.

§ 108. A number of experiments were also tried by Prof. Henry, to determine the best form of the iron to receive magnetism; but not with very satisfactory results. A hollow iron cylinder, which had formed part of a gun-barrel, was found to be capable of receiving more magnetism than the same quantity of metal in a solid cylinder of less diameter, but not as much as a solid bar of the same dimensions; and this fact was considered analogous to those observed by Mr. Barlow (see § 85), which led him to conclude that "magnetic power resides wholly on the surface of iron bodies, but that a certain thickness of metal is necessary for its complete development."

§ 109. While the above investigations were in progress in this country, Prof. Moll, of Utrecht, made some experiments with one of Mr. Sturgeon's electro-magnets, which he procured of Mr. Watkins, in London; the object of which was to try the effect of using powerful single batteries. With a battery presenting a zinc surface of eleven square feet, the magnet lifted 75 pounds; but a battery of seventeen feet, and also one of very great size, gave no increase of magnetic power. This result is confirmatory of those given in (§ 106).

He then sought to produce greater effects, by using a horse-shoe $12\frac{1}{2}$ inches high and $2\frac{1}{2}$ inches in diameter, which lifted 154 pounds

with the same battery. But that he had no idea of the effect of increasing the number of spires of the magnetizing helix, is evident from the fact that he wound the larger magnet with only forty-four turns of uncovered copper wire, while the number of similar spires on the smaller magnets was eighty-three, or nearly twice as many.

Prof. Moll, however, observed particularly the instantaneous destruction and reproduction of magnetism, which takes place when the current is reversed, by changing the connection of each end of the helix from one pole of the battery to the other. This prompt action of the magnet is essential to the usefulness of the electro-magnetic telegraph, and on that account the same fact has since been experimented upon and confirmed by Mr. Vail, who is associated with Prof. Morse in his valuable enterprise.

§ 110. As the claims of Prof. Moll have been asserted to the prejudice of those of our fellow countryman, it may here be remarked, that the former employed one of Mr. Sturgeon's magnets, purchased of Mr. Watkins, and only thought of increasing the size of the horse-shoe when he failed to obtain any greater development of magnetism by using much larger and more powerful batteries. Prof. Henry, on the contrary, thoroughly investigated the effects of varying the quantity and intensity of the battery current, the size and form of the horse-shoe, the number of spires of the helix, and the resistance of the conducting wires. The experiments of Prof. Moll were very incomplete, and though they were published shortly before the researches of Prof. Henry, yet the latter had discovered in 1828, and exhibited to the Albany Institute in March, 1829 (two years previously), the fact that the current of a small galvanic element passed through a wire covered with silk and wound 400 times around a horse-shoe of soft iron, rendered it more powerfully magnetic than a similar horse-shoe wrapped loosely with a few turns of an uncovered wire, and excited by a battery of 28 plates of copper and zinc, each 8 inches square.

§ 111. Having fully investigated the phenomena of electro-magnetic induction, Prof. Henry was enabled to make soft iron magnets of wonderful power. One in the cabinet of Yale College, weighing 59½ lbs. (exclusive of the copper wire around it), was formed of a bar of iron three inches square and thirty inches long; it was wound with 26 strands of copper bell-wire covered with cotton thread, and 31 feet long; about 18 inches of the ends are left projecting, so that only 28 feet actually surround the iron; the aggregate length of the coils is therefore 728 feet. Each strand is wound on a little less than an inch; in the middle of the horse-shoe the wire forms three thicknesses, and on the ends or near the poles it is wound so as to form six thicknesses. This magnet supported 2063 lbs., or nearly a ton, with a battery exposing a zinc surface of nearly five square feet. The effect of a larger battery was not tried.

Another, and the largest of these magnets constructed by Prof. Henry, is in the cabinet

of the College of New Jersey, and the following is his description of it:—It is formed of a bar of rounded iron, nearly four inches in diameter, weighing about 100 lbs., and surrounded with 30 strands of copper bell-wire, each about 40 feet long. With a calorimeter on Dr. Hare's plan, consisting of 22 plates of zinc each 9 inches by 12, alternating with plates of copper of the same size, it supports 3500 pounds, or more than a ton and a half.

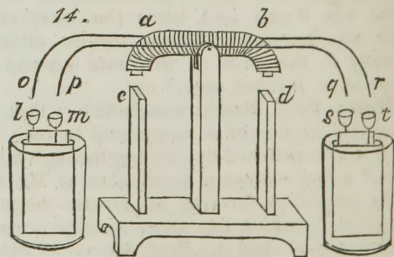
After the connection with the battery is broken, this magnet supports a thousand pounds for several minutes; and from year to year the lifter adheres with a force which is overcome only by a weight of several hundred pounds. When the lifter, however, is detached, nearly all the magnetism disappears.

It is evident that, by increasing the size of the iron bar, the number of the coils, and the power of the battery, the magnetic power may be almost indefinitely extended.

§ 112. That a force of such great strength may be applied to the production of mechanical effects, is an idea which would naturally arise in any mind; and that Prof. Henry should, therefore, have been the first to attempt such an application, is almost a consequence of his previous researches. In Silliman's Journal for 1831, vol. xx. p. 340, he described a machine for producing a reciprocating motion, "by a power never before applied in mechanics,—by magnetic attraction and repulsion." Of which he remarks, "Not much importance, however, is attached to the invention, since the article, in its present state, can only be considered a philosophical toy; although, in the progress of discovery and invention, it is not impossible that the same principle, or some modification of it on a more extended scale, may hereafter be applied to some useful purpose."

It consisted of a horizontal electro-magnet of soft iron, *ab* (fig. 14), seven inches long, wound with three strands of covered copper wire, and movable upon an axis at its centre. Beneath the ends of the horizontal bar, two vertical magnets, *c* and *d*, were placed, with their north poles upwards. Each extremity of the magnetizing wire was divided into two lateral branches at the axis, so that by the vibrations of the bar, contact would be alternately made and broken with cups of mercury attached to dissimilar plates of two galvanic batteries suitably placed at the sides.

"When the batteries are in action, if the



end *b* is depressed until the wires *q, r*, dip into the cups *s, t*, the bar *ab* instantly becomes a powerful magnet, with its north pole at *b*,

which is of course repelled by the north pole d , while at the same time the end a is attracted by c ; the position is consequently changed, and a, p , come in contact with the mercury in l, m ; as soon as this communication is formed the poles are reversed, and the position is again changed."

Of the substitution of galvanic magnets for the two perpendicular steel ones, Prof. Henry further remarks, that "if an article of this kind was to be constructed on a large scale, this would undoubtedly be the better plan, as magnets of that kind can be made of any required power; but for a small apparatus, intended merely to exhibit the motion, the plan here described is perhaps the most convenient."

§ 113. The next person who contrived a modification of the above-described electro-magnetic machine, was Prof. Ritchie, of the London University, who published an account of it in 1833, in the transactions of the Royal Society.

In 1834 Mr. Davenport, an ingenious blacksmith of the State of Vermont, having seen a powerful electro-magnet, contrived a machine upon the same principle, which was exhibited in 1837, in the principal cities of the United States, but resulted in no useful or valuable application, though an attempt was made to drive a printing-press with it.

Of more recent attempts to apply this power, one made on the Edinburgh and Glasgow Railway, by Mr. Davidson, who constructed an electro-magnetic locomotive, 16 feet long, 6 feet broad, and weighing 5 tons; and another by Prof. Jacobi, of St. Petersburg, at the expense of the Russian government, may here also be mentioned. That of Mr. Davidson failed to propel the engine alone more rapidly than four miles an hour; but Prof. Jacobi drove a boat 28 feet by $7\frac{1}{2}$, drawing $2\frac{3}{4}$ feet of water, at the rate of three miles an hour against the stream, with a party of about a dozen persons on board.

It is evidently possible, when we possess a source of mechanical power to accumulate it, either by employing one very large engine, or a number of smaller ones. The question whether or not electro-magnetic forces can be rendered practically useful, depends not, therefore, so much upon the amount of power required, as upon considerations of economy. Water and fuel are found everywhere in Nature in the greatest abundance, while zinc and acids are manufactured articles, of high comparative cost. An engine which consumes such substances in large quantity cannot, therefore, be employed with profit in competition with steam. And this conclusion, based upon theoretical reasons, is fully confirmed by experiments with such machines.

It should also be borne in mind, in estimating the effective working power of an electro-magnetic engine, that the forces vary inversely as the square of the distance; and, therefore, that though a magnet, such as those of Prof. Henry, acts with a *cohesive* attraction of more than a ton *in contact*, or at infinitely small distances, it exerts when contact is broken, or at appreciable distances, a force of only a few pounds.

§ 114. The fact mentioned in (§ 111), that the armature or lifter of a large electro-magnet adheres with a force of several hundred pounds from year to year, after connection with the battery is broken, or the magnetizing cause has ceased to act, shows that there is nothing improbable in the hypothesis of Ampère, that electrical currents circulate constantly around the axes of the magnetic molecules. And, indeed, the planetary motions, as well as correct mechanical ideas, have fully established the truth that a state of motion, in the absence of resistance, will continue indefinitely. In the present state of our knowledge of the constitution of matter, we have reason to believe that no two atoms can possibly be brought into absolute contact; and that an ethereal fluid, such as electricity may be supposed to be, may revolve perpetually in their intervening spaces, is, therefore, neither an improbable hypothesis, nor one without analogy in Nature.

§ 115. *Induction of Electricity by Magnetism.* Having shown, with reference to the phenomena of attraction and repulsion, that electro-dynamical cylinders and magnets may be mutually substituted for each other; and that they also produce similar results, when they act inductively upon ferruginous bodies; it remains only, to complete the exposition of their analogous effects, that we should discuss the subject of the development of electrical currents by magnetism.

Our knowledge of this subject we owe chiefly to the able researches of Dr. Faraday (§ 101), which were undertaken by him with the hope of obtaining electricity from ordinary magnetism, and by reason of the consideration, that "whether we adopt the beautiful theory of M. Ampère or another, or make any mental restriction whatever, it seems very extraordinary, that as every electrical current is accompanied by a corresponding intensity of magnetic action at right angles to the current, good conductors of electricity, when placed within the sphere of this action, should not have a current induced through them, or some sensible effect produced, equivalent in force to such a current." That his labors resulted in perfect success is not only a fact of importance in the history of electrical science, but also one which strikingly illustrates the utility of physical theories, in suggesting and directing experimental inquiries.

Dr. Faraday began his researches by the careful study of the phenomena caused by the inductive action of electro-dynamical helices upon each other; and then substituted magnets in the place of such helices, for the production of electrical currents. Under the head of *Electro-dynamical Induction* (§ 58—64), we have presented all the principal facts of that subject as analytical consequences of Franklin's theory, to which Prof. Henry has satisfactorily referred them. Here we shall enumerate such of those facts as were discovered by Faraday before Prof. Henry commenced his investigations; not only for the purpose of doing justice to the claims of both of these philosophers, but also because most of the phenomena discovered by Faraday may

be referred to the electro-dynamical theory of magnetism of M. Ampère, and are therefore connected with this division of our general subject.

§ 116. Two covered metallic wires, more than a hundred feet long, were wrapped contiguously around a cylinder of wood, so as to form concentric and parallel electro-dynamical helices, the successive spires of which were close together, but not in metallic contact. With this apparatus, whenever connection with a compound battery was formed with one helix, a momentary *inverse* current took place in the other helix. During the flow of the battery connection, no induced current could be detected; but when it was interrupted, a *direct* current was induced in the second wire, which also lasted only for an instant.

These induced currents, and their directions, were indicated by the deviations of the galvanometer which they produced; and also by their magnetizing effects upon steel needles.

§ 117. Two long and similar wires, bent zigzag, or in the form of the letter W, were attached to pieces of board, which could be made to approach or recede from each other. One of these wires being connected with a galvanic battery, and the other with a galvanometer or magnetizing spiral, Dr. Faraday found that when they were made to approach or recede from each other, an induced current takes place, the direction of which is *inverse* in the former, and *direct* in the latter instance. But when the wires were stationary, no current was induced.

§ 118. A round bar of soft iron, $\frac{7}{8}$ ths of an inch thick, was made into a ring six inches in diameter; and each side of this ring was wound with an insulated copper wire. When one of the wires was attached to a battery, and the other to a galvanometer or magnetizing spiral; it was observed that an *inverse* current was induced at the moment of forming battery contact, and a *direct* current at its ending; but no current was induced while the flow of the battery current remained constant.

These induced currents were found also to be far more energetic in their action upon the galvanometer than those produced by helices alone. And by adapting charcoal tips to the ends of the second helix, with the last arrangement, a spark was even obtained from the induced current, at the instant of interrupting the battery current in the primitive helix.

§ 119. That the magnetism induced in the iron ring is the cause of the increase of energy in the secondary current of the last experiment, was fully proved by the following results.

Two concentric and insulated electro-dynamical helices being wound upon a hollow cylinder of pasteboard, instead of a solid piece of wood, as in the arrangements of (§ 116), gave but feeble induced currents. But when a bar of soft iron, $\frac{7}{8}$ ths of an inch thick and 12 inches long, was introduced into the interior of the pasteboard cylinder covered with the wire helices, the induced currents were very powerful; yet this arrangement was not as energetic as that of the iron ring. When a bar of copper was substituted for that of iron,

no increase of the effect of the helices alone was produced.

§ 120. Similar inductive effects were observed, when the corresponding ends of the helices were united, so as to form a single helix attached to the galvanometer, and the opposite poles of two steel magnets were suddenly brought into contact with, or removed from the ends of the soft iron bar surrounded by the pasteboard cylinder and the helix.

With powerful magnets induced currents were also produced, by bringing their poles near to, but without touching the ends of the enclosed iron bar.

Lastly, it was found by Dr. Faraday, that induced currents are produced whenever either pole of a magnet is quickly introduced into, or removed from a helix of copper wire.

§ 121. In all these experiments, perfect uniformity was observed with reference to the directions of the induced currents, and the circumstances of their development. No secondary current being produced except by a change either of intensity or of distance in the exciting current or magnet; and the directions of the induced currents being always opposite to those of the inducing currents, whether the latter be real, as in the conducting wires of batteries, or hypothetical, as required by the theory of M. Ampère.

§ 122. These beautiful researches of Faraday evidently render the existence of electrical currents in magnets highly probable. And they compel us to admit that, if the close and extensive analogy between the observed effects of magnets and electro-dynamical cylinders, does not justify us in concluding that M. Ampère has discovered the true connection between all magnetic and electrical phenomena, we yet must consider his theory as the expression of some equivalent physical relation of a very high order of generality.

§ 123. There are two facts, however, which seem not to be accounted for by M. Ampère's theory:—1st. That the hypothetical induced currents of magnetic and electro-magnetic induction are *direct*, while the secondary currents of electro-dynamical and magneto-electrical induction are *inverse*. 2d. That magnetic induction is a permanent effect of a constant cause, while the electrical currents induced by magnetism or by similar currents are temporary, and require a change of intensity for their production.

These apparently anomalous truths require further investigation for their theoretical exposition; and they are doubtless intimately connected with the mysterious and hitherto inexplicable fact, that iron and a few other metals only, of all good electrical conductors, are susceptible of any considerable degree of magnetism.

§ 124. With reference to the application of Ampère's theory to the development of magnetism in soft iron, we may either suppose that electrical currents possess the power of causing the natural electricity of the metallic particles to pass into a state of rotary motion from one of rest, or that elementary currents flowing in every direction around each molecule, pre-exist in iron, and are only made to

assume similar and parallel directions (see § 73), by the influence of the inducing current or magnet. The latter of these suppositions would render the phenomena of magnetic induction somewhat analogous to those of the polarization of light; while it also accounts for the difference of direction and duration (§ 123), found to exist with reference to magnetical and electro-dynamical induction. Nor is the pre-existence of elementary currents in a few of the metals, a more arbitrary hypothesis than that of two magnetic fluids of opposite natures, assumed by the theory of Coulomb to reside only in the atoms of the same metals.

§ 125. One of the distinguishing features of a physical law is, that it should be capable of embracing facts which appear inexplicable, until new light is unexpectedly thrown upon them by the investigation of some analogous though simpler truth. This is exemplified by the prompt application which Faraday made of his discovery of electro-dynamical induction to explain certain singular phenomena, first observed and studied by M. Arago. When a delicately suspended needle, the oscillations of which had been previously observed, was enclosed in a copper box, M. Arago was surprised to find that it vibrated through arcs of smaller and rapidly decreasing extent. That this effect was due to some action of the metallic box upon the needle, he proved by vibrating the latter over discs of pure copper of various thicknesses, with similar results; which, also, were not affected by interposing membranes of paper and other substances. M. Arago then tried the effect of giving motion to the disc instead of the needle, and found that when it revolved with different degrees of velocity, the needle was deflected from the magnetic meridian, through angles of proportional magnitude; and when the disc was made to rotate with great rapidity, the needle even revolved in the same direction. In these experiments a plate of glass was interposed, to prevent the effects of currents of air.

These phenomena were further investigated by Messrs. Babbage and Herschel, who caused large discs of copper and other metals to revolve with great rapidity, by the inductive influence of a powerful rotating magnet. They also found, that the impulsive or rotary force is greatly weakened, by cutting the disc radially, so as to remove narrow slips from the circumference to the centre; and that its energy is restored by filling these cuts with solder, so as to re-establish the metallic continuity of the disc.

The limits of this article do not justify us in giving a full account of these highly interesting phenomena, nor permit us to do more than merely indicate how the discoveries of Faraday serve to explain them satisfactorily, by referring them to the established laws of electro-dynamical forces.

Since induced electrical currents are formed in any metallic body by varying its distance from a magnet (§ 120, 121), the direction of which is *inverse*, or opposite to that of the hypothetical currents of the magnet, when the distance diminishes, and direct when it in-

creases, it follows that, in the portion of a copper disc which approaches a magnet, by the rotary motion of either, inverse currents will be developed, and that direct currents will be induced in the receding portion. The former, according to the theory of Ampère, should exert a repulsive, and the latter an attractive force (§ 91); both of which forces tend to produce motion in the same direction as that of the revolving body.

The existence of such induced currents was also proved by Faraday, by attaching the ends of a metallic wire to the moving disc, in such a manner that the currents were drawn out and rendered sensible by a galvanometer.

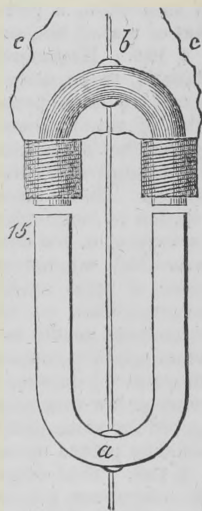
§ 126. The next important step in the progress of this branch of electrical science, was the independent invention of the magneto-electrical machine, by M. Pixii, of Paris, and by Mr. Saxton, of Philadelphia, then residing in London. This ingenious machine depends upon, and was the immediate fruit of, the discoveries of Faraday (§§ 118—120); and by it all the effects of electrical currents, as, for instance, sparks, shocks, decomposition, deflagration, etc., may readily be produced.

The magneto-electrical machine consists essentially of a permanent magnet, *a* (fig. 15),

and of a soft iron armature, *b*, wound with an insulated copper wire, *cc*; either the magnet or the armature is made to revolve rapidly around the axis or middle line, *ab*, so as to bring each pole of the former successively near to either end of the latter; the soft iron of the armature thus becomes alternately magnetized with opposite polarity, and currents flowing in contrary directions are induced in the copper wire. If a closed circuit be formed by connecting the ends of the wire *cc*, all of the induced currents are transmitted; but if by any suitable mechanical arrangement contact be broken during one half of every revolution, one half of the currents will be interrupted, and those transmitted will all have the same direction. In the machine contrived by M. Pixii, the magnet revolved and the armature was stationary; in that of Mr. Saxton, motion was given only to the latter.

This ingenious and valuable machine was improved by Mr. Clarke, by employing two armatures instead of one (see §§ 61, 62). A *quantity armature*, wrapped with a short thick wire, for effects of quantity, and an *intensity armature*, made of a bar of soft iron of one half the size of that used in the former, and wound with a finer and much longer wire.

Another important modification of the magneto-electrical machine was made in 1838 by Mr. Page, of the U. S. Patent Office, and subsequently by Prof. Wheatstone, of London, with-



out a knowledge of the invention of Mr. Page. It consists of a number of such machines as that of Mr. Saxton, so combined as to produce a continuous current in one direction, which is done by connecting the ends of each coil with a single conjunctive wire, and fixing the armatures upon a single revolving axis, at such angles that the induced current in one commences when that in another ends.

In his original memoir on magneto-electrical induction, Dr. Faraday suggests that, for the production of powerful effects, Prof. Henry's electro-magnets may be employed. And this suggestion has been acted upon by Prof. Callan, of Ireland, who constructed a very large machine, in which an electro-magnet, formed of iron bars *thirteen* feet long, was substituted for a steel magnet; with this machine, small animals are said to have been instantly killed, and other energetic effects produced.

§ 127. *Magnetic Induction upon Bodies which are not ferruginous.* Besides iron, the only metals which have long been known to be susceptible of magnetism in any considerable degree, are nickel and cobalt.

M. Biot possessed a bar of nickel which had been purified by Thénard with all possible care, and which acquired, when magnetized to saturation, a power equal to one-third of that of a steel magnet of the same size.

§ 128. Hammered brass was found, by Cavallo, to be often magnetic; but he could detect no such property in either copper or zinc, of which brass is formed. He also observed that brass loses any magnetism it may have acquired by hammering, when it is annealed. These facts are important in their relation to magnetic instruments employed for surveying, or for observing the phenomena of terrestrial magnetism. Mr. Barlow found a piece of brass attached to a compass, which he examined, so strongly magnetic that it caused the needle to vibrate 14 or 15 degrees, when applied outside the glass, and retained the same $1\frac{1}{2}$ degrees out of its true direction; every screw and attached piece had also acquired the same quality, so that no dependence could be placed upon the instrument.

§ 129. That magnetism may be developed in substances generally, was first shown by Coulomb, in 1812. The bodies experimented upon were made into small cylindrical needles, which were suspended by a silk fibre, and vibrated horizontally between the opposite poles of two steel magnets. They always assumed a position of equilibrium, in the direction of the line joining the poles of the magnets; and when disturbed, returned to this position by a series of oscillations. The vibrations were also much quicker, under the influence of the magnets, than those of the same needles when the magnets were removed: thus proving the existence between them of an attractive force. Gold, silver, and other metals purified with extreme care, as well as glass, wood and various substances, organic and inorganic, all gave like results.

To explain these effects, Coulomb was compelled to infer, either that all bodies are susceptible of magnetism, or that they contain iron or some other magnetic metal in suffi-

cient quantity to be appreciable by his delicate torsion balance, but too small to be detected by chemical analysis.

To determine the probability of the latter hypothesis, he formed small cylinders of iron filings and bees-wax, mixed in different proportions; from the times of vibration of which he calculated the forces exerted upon them by the same magnets (§ 18), and found these forces proportional to the quantities of iron the cylinders respectively contained.

Coulomb then divided each of the cylinders into four or five others of the same length, but of which the masses were of course much less; by suspending and oscillating these portions under the influence of the magnets, he found their times of vibration exactly equal to those of the original cylinders from which they were made; whence it follows, that the forces exerted upon each needle are exactly proportional to its mass. This result was also found to hold good for small cylinders of the same length, but of unequal thicknesses, made from an ingot of silver separated from iron by simple fusion, and which evidently retained a portion of iron, because detached particles were sensibly attracted by magnets; though, when this silver was dissolved in nitric acid and tested with prussiate of potash, not the slightest shade of blue could be perceived.

Having thus proved that the forces exerted are proportional in each instance to the mass, and to the quantity of iron in any ferruginous body, Coulomb determined the proportion of iron in the above-mentioned silver to be $\frac{1}{320}$ th part, by comparing the oscillations of a needle made of it with those of one of equal length, composed of a mixture of wax and iron filings. And this result enabled him to estimate the proportion of iron still retained by metals purified by chemical processes considered the most exact; such as silver refined by cupellation, or reduced from the chloride of silver. The forces exerted upon a needle of such purified silver, and one of equal length composed of the above-mentioned ferruginous silver, were found to be in the ratio of 1 to 415; so that the proportion of iron which may be in the former is $\frac{1}{415}$ th of that in the latter, or $\frac{1}{172800}$ th of its own mass,—a quantity far too small to be detected by the most delicate chemical analysis.

Hence it appears, that the hypothesis which attributes the above-mentioned phenomena to the accidental presence of iron, is fully sufficient for their explanation; and also that the proportion of iron required is so very small, that it may with probability be supposed to exist in all substances, and to escape detection by chemical reactions.

§ 130. Recently, this subject of the action of magnets upon all bodies has attracted particular attention, and acquired much additional importance, in consequence of its probable connection with a very remarkable phenomenon discovered in 1845, by Dr. Faraday (§ 134, *infra*), that magnets and electro-dynamical cylinders possess the power of acting inductively upon certain transparent bodies, in such a manner as to cause a transmitted ray of

polarized light to rotate upon its axis; we shall, therefore, endeavor to state succinctly what had been done by others before Faraday made his interesting experiments.

§ 131. In 1827, M. Becquerel found that a small paper tube, containing a mixture of the sesquioxide and magnetic oxide of iron, in various proportions, assumes a direction perpendicular to the axis of a bar magnet, when its centre of suspension is placed as near as possible to one of the ends of the magnet. This he attributed to the development of magnetism transversely, instead of longitudinally, as in soft iron; and he observed that the transverse magnetism of such a mixture is somewhat permanent, however small the quantity of magnetic oxide it contains. Also, by varying the position of the centre of suspension, with reference to the pole of the magnet, the needle was made to assume various directions, parallel, oblique, or perpendicular to the axis of the magnet. Similar results were obtained when the paper tube was filled with the sesquioxide of iron alone; but its oscillations, when disturbed, were much slower, thus indicating a less energetic action.

Needles made of gum-lac, of wood, or of any other substance, gave analogous effects; but, as the magnetism of these substances is much feeble than that of the oxide of iron, it was necessary to employ two powerful magnets. The suspended needle was placed between the opposite poles of the magnets, the ends of which were only a few millimetres apart, and the point of suspension was as near as possible to the interval which separated them. The needle then placed itself perpendicularly to the line of the poles, and not as in the experiments of Coulomb; but when the ends of the magnets were gradually moved further apart, the needle by degrees assumed the direction of the line of the poles.

Hence, M. Becquerel concluded, that the magnetic effects produced in iron and steel, by the influence of a magnet, differ from those which take place in bodies generally, in that in the former the distribution of the magnetism is longitudinal, while in needles of sesquioxide of iron, wood, gum-lac, etc., it takes place transversely. Also, that this difference depends upon the circumstance, that the magnetism of such bodies is so feeble that we may neglect the reaction of the particles upon each other.

§ 132. M. Lebaillif, in 1829, having contrived a very delicate magnetometer, which he called a *sideroscope*, found that nearly all bodies exerted upon it a feeble action, which could in most cases be attributed to the presence of iron in small quantity. Bismuth and antimony were, however, found to act *always* repulsively.

§ 133. M. Edmond Becquerel observed that, when the opposite poles of two powerful magnets are placed within 2 or 3 millimetres of each other, and a needle of wood, copper, etc., 5 or 6 centimetres long, is suspended by a silk fib reover the interval which separates them, at the distance of about a millimetre, it will place itself transversely. But if the needle be divided successively, fragments will soon

be obtained which will arrange themselves longitudinally. This result he considered a corollary of those of his father (§ 131), by which it appears that the same substance may be made to assume different positions, by varying its distance from the poles.

Also, in a memoir presented to the Academy in June, 1845, M. Ed. Becquerel stated that he had found the presence of iron in much smaller quantity than $\frac{1}{132800}$, the proportion given by Coulomb (§ 129), to be sufficient to explain the action of magnetism on bodies generally. And that he had determined the ratio of the intensity of the forces exerted upon transparent and other bodies to those upon iron, nickel and cobalt, to be comprised within the limits of zero and 0.00002, varying with the particular substance. Hence, he concluded that, as a mean result, magnetism acts upon transparent bodies with a force 100,000 times more feeble than upon iron.

He also found that the attractive and directive action of magnets upon transparent substances changes with the purity of the specimens, and of some (silica, iodine, etc.), that needles may be obtained which seem not to be affected at all; whence he infers, that such bodies act like mixtures of inert matter with magnetic particles, and that in many instances the observed effects are probably due, as Coulomb supposed, to the presence of iron.

§ 134. Finally, in November, 1845, M. Faraday presented to the Royal Society a memoir, of which an analysis was given by him in a letter to M. Dumas, communicated to the Academy of Sciences of Paris (see *Comptes Rendus*, t. xxii. p. 113), and of which letter the following is a translation.

§ 135. "If the *line of magnetic force* produced by a powerful electro-magnet, or by a helix, be made to pass through a transparent body, in a direction parallel to that of a ray of polarized light, which traverses the same body, the ray of light will undergo rotation. This effect is produced in all transparent bodies, liquid or solid, which are not endowed with double refraction, but in different degrees according to the nature of the substances. I consider it a magnetic action exerted upon the luminous ray itself; but several of my friends, who however have not had equal opportunity of considering all the facts of my memoir, are of the opinion that this phenomenon proves no such thing. Hence, though my own opinion remains unaltered, I cheerfully acknowledge that it may be erroneous.

§ 136. "If the ray of light suffers rotation to the right for a certain given direction of the magnetic force, or of the current in the helix, it will experience it to the left for the contrary direction of the magnetic or electrical forces. The nature of the rotation depends essentially upon the direction of those forces, which constitutes a remarkable difference between this rotation and that of quartz, sugar, oil of terpentine, etc., as shown in the following manner:

§ 137. "Place side by side, within a helix, a tube of water and a tube containing oil of terpentine. If the oil possesses rotation to the right, cause an electrical current to pass

through the helix, in the direction required for rotation to the right, the water in the tube will acquire a rotary power to the right, and the two liquids will possess the same mode of action.

"Leave now the tubes, the helix and the current in the state we have just described, but cause the ray of polarized light to pass in the reverse direction through each tube, and observe it at the opposite end. The oil of turpentine will still rotate to the right, but it will not be so with the water, which will rotate to the left. The rotation is absolutely connected with, and governed by the direction of the electrical current; and when seen from this extremity, is therefore to the left.

"If, instead of water, we put oil of turpentine in the helix, and the electrical current be sufficiently intense to produce a rotation of the ray of light equal to that caused by the turpentine, its rotary power observed for a ray passing in one direction will appear to be doubled; but for a ray in the opposite direction, it will be reduced to zero. This fact is that upon which especially I base my opinion in opposition to that of my friends, or rather of some of them.

§ 138. "Now, with reference to the magnetic condition of matter, the following are results which I have found:—That all matter in the solid or liquid state (perhaps also in the gaseous), is affected by magnets, but not as iron would be. A substance magnetic after the manner of iron, is *attracted* by a magnet; and a portion of such a substance of an elongated shape, places itself in the directions of the lines of magnetic force; while a substance which is not magnetic like iron, is *repelled* by a magnet; and an elongated portion of such a substance assumes directions transverse to the lines of magnetic force. Water, alcohol, ether, oil, wood, flesh, blood and a thousand other substances, possess this latter magnetic relation; but the best are perhaps silico-borate of lead, phosphorus, antimony and bismuth. Probably you recollect that (nearly thirty years since, I believe) M. Lebaillif, of Paris, observed the repulsion by magnets of antimony and bismuth; I have mentioned this fact in a general manner, and referred to it in my memoir.

§ 139. "Having designated those substances which are not magnetic like iron by the name of *diamagnetics*, I have kept this name to express this new magnetic state; and in repetition, I may say that every solid or liquid substance exerts and suffers a magnetic influence, the nature of which is either *magnetic* or *diamagnetic*.

"From this property and its study arise a multitude of curious conditions, for which I must refer you to my memoir. Among other things, I have found that the ordinary compounds of the magnetic metals are equally magnetic. Thus, the oxides of iron are not the only magnetic compounds of that metal, as M. Becquerel and others have supposed; but all its salts are so likewise, as well as solutions of these salts, sufficiently concentrated to counteract the diamagnetic force of the water or alcohol used for dissolving them.

§ 140. "By proceeding thus, I have been able to determine that cerium is a magnetic metal, for all its salts are magnetic; and that the same is true for chrome and manganese."

§ 141. The difference of opinion to which Faraday refers in the above letter (§§ 135, 137), seems to be a matter rather of misapprehension than of actual discordance of views. For no one can deny, that a polarized ray of light is affected, when it is decomposed into rays of various colors, rotated through different angles. And, on the other hand, Faraday himself observes, in his original memoir (2224): "The magnetic forces do not act on the ray of light directly and without the intervention of matter, but through the mediation of the substance in which they and the ray have a simultaneous existence; the substances and the forces giving to, and receiving from each other the power of acting on the light. This is shown by the non-action of a vacuum, of air and of gases; and it is also further shown by the special degree in which different matters possess the property." Also, in (2226), he says:—"It cannot be doubted, that the magnetic forces act upon and affect the internal constitution of the diamagnetic just as freely in the dark as when a ray of light is passing through it; though the phenomena produced by light seem, as yet, to present the only means of observing this constitution and change. Further, any such change as this must belong to opaque bodies, such as wood, stone and metal; for as diamagnetics, there is no distinction between them and those which are transparent. The degree of transparency can at the utmost, in this respect, only make a distinction between the individuals of a class."

There is certainly no discrepancy between such views and those of M. Pouillet (*Comptes Rendus*, t. xxii. p. 146), who first repeated and confirmed the electro-optical experiments of Faraday, and who thus expresses himself:—"If it ever happens, that bodies which are very sensitive to the optical action, are insensible to the mechanical action of magnetism, it would be no reason for concluding that magnetism acts directly upon light itself,—a conclusion which would have a definite meaning only in the system of emission; for, in the undulatory theory which now seems to be so completely established, it is the æther of the body which would be modified by the magnetism."

There appears, however, to be some want of consistency in the expressions of Faraday, when we compare his letter to M. Dumas (see § 135) with the passages of his memoir, given above. But upon this point we must, in justice, refer the reader to the entire memoir itself, rather than to extracts from it.

§ 142. Whatever may be the correct theoretical exposition of this electro-dynamical inductive action upon a ray of polarized light, and especially of the remarkable difference between the rotation it produces, and that of circularly polarizing substances (§§ 136, 137), the discovery itself is certainly one of the highest importance, and constitutes one of the

most brilliant trophies of the inventive genius and indefatigable industry of its distinguished author.

§ 143. Lastly, in his memoir (2199), Faraday remarks, "The LAW by which an electric current acts on a ray of light, is easily expressed. When an electric current passes round a ray of polarized light in a plane perpendicular to the ray, it causes the ray to revolve on its axis as long as it is under the influence of the current, in the same direction as that in which the current is passing." Likewise, in (2239), "All bodies are affected by helices as by magnets, and according to laws which show that the causes of the action are identical as well as the effects. This result supplies another fine proof in favor of the identity of helices and magnets, according to the views of Ampère."

§ 144. With reference to the facts mentioned in the second part of Faraday's letter to M. Dumas (§§ 138, 139), and which relate to a repulsive action of magnets on bodies generally, the following additional information may here be given.

That the force is truly one of repulsion, was shown by subjecting cubes, spheres, etc., to its action. Thus (2265), when two pieces of glass are hung up, one near each pole, in the line joining the poles of a very powerful electro-magnet, they recede from their respective poles and approach, seeming to attract each other. But when hung up, one on each side and at the middle of that line, they both recede from it, and seem to repel each other.

That the transverse directive tendency of elongated substances is due to repulsion, was proved by the fact (2266) that, "When a cube was thus used with the two poles, the effect was repulsion or recession from either pole, and also recession from the magnetic axis on either side."

§ 145. This repulsive action of magnets on bodies was also found, by Faraday (2283), to be independent of their state of division. Thus, the effect was the same as to the degree of directive force, with a piece of Iceland spar when entire or broken into fragments, or reduced first to a coarse, and subsequently to a fine powder. Similar experiments with silica were made with the same result. Also, various pulverized bodies were found to exhibit the action very well.

§ 146. It is evident that, when masses of metal or of other conducting substances are made to vibrate near the poles of a magnet, the effects of the statical repulsive forces will be modified by the action of electrical currents induced in the moving body (§ 125), as in the phenomena first observed by Arago. Such modified effects, as exhibited by a suspended copper bar, were particularly studied by Faraday, and form an interesting portion of his memoir, to which, for full information, the reader is referred.

§ 147. It is to be desired, that the general results of Faraday, with reference to the repulsion of bodies by magnets, should be confirmed by equally skilful persons. For much discrepancy seems to exist between his experiments and those of MM. Coulomb, Becquerel

and others (§§ 129—134); and the forces are so feeble (§ 133), that they seem scarcely to be appreciable, except by means of the most delicate apparatus, and with very powerful magnets.

§ 148. M. Pouillet found that bismuth and amber are repelled, when sprinkled in the state of powder, and gently shaken upon a sheet of paper over either pole of a magnet; which experiment had also been performed by Faraday (2304), with the same result. By this method, M. Pouillet likewise proved that "the compounds of magnetic metals are more or less magnetic" (§ 139); but he was unable to detect any attractive or repulsive effect on antimony or the other non-magnetic metals. He, however, justly says, that "These negative results cannot invalidate in the least the general proposition of Faraday, who doubtless operated with more delicate means or with more energetic magnets. And they are only mentioned to point out the easy process employed, and the limit of its sensibility." It may here also be observed, that M. Pouillet had shown that manganese and chromium are magnetic metals, some time before Faraday (§ 140) confirmed the same fact.

§ 149. *Musical Sounds produced by Electromagnetic induction.* In 1837, it was discovered by Dr. Page, of the U. S. Patent Office, that a musical sound may be produced by the magnetization of a bar of iron, owing probably to some new molecular arrangement of its particles. And this phenomena has lately been particularly studied by M. de la Rive and others. When a discontinuous current is sent through a helix around a bar of iron, or through a stretched iron wire, both transverse and longitudinal vibrations are produced, giving rise to two distinct sets of sounds. That the action is internal and molecular, M. de la Rive considers as fully proved by the following facts:—1, a bar of iron, four inches thick, gives a clear musical sound, and cannot be supposed to suffer change from external mechanical force; 2, the sound of a wire acted upon by a discontinuous current in a helix, changes when a current passes through the wire, or when it is magnetized by contact; 3, a wire through which a constant current flows, gives no sensible sound when a discontinuous current passes through it, though the currents move in the same direction: as if the former produces a permanent state or *set* of the particles; 4, a discontinuous current produces little or no sound when sent through a permanently magnetic wire.

§ 150. Closely connected with the molecular changes just mentioned, is a fact observed by M. Guillemin, that the elastic force of a bar of soft iron is increased by magnetizing it. He found that a bar firmly fixed at one end, and supporting at the other a weight sufficient to bend it, sensibly straightens itself and elevates the weight, when a current passes through a helix tightly wound upon the bar.

§ 151. *Causes which Modify Magnetic Induction.* We have already stated (§§ 77—79), that magnetism is developed temporarily in soft iron, but permanently in steel and the loadstone. Hence it appears that chemical

combination and molecular structure modify the action of magnetic forces in a very remarkable manner.

Also, we have seen (§ 80) that, to explain such phenomena, *Æpinus* found it necessary to suppose the magnetic fluid of his theory to move freely in pure iron, but with difficulty in steel, &c.; as electricity passes readily through conductors, but is effectually resisted by non-conductors. And similarly, in the theory of *Coulomb* (§ 82), the separation of the two hypothetical fluids in the molecules, as well as their reflux from this polar or separated state, by virtue of mutual attraction, is supposed to meet with greater or less resistance in different substances.

§ 152. This resistance, which is overcome by the inductive force in the development of magnetism, and which tends to maintain a state of tension when established, has been called the *coercitive force*. Whatever may be the unknown physical cause, the term itself is convenient, and we shall therefore employ it.

If we adopt the electro-dynamical theory of *Ampère*, we are no less at a loss, in the present state of our magnetical knowledge, to account for the various degrees of coercitive force exerted by different bodies similarly acted upon, or by the same body under dissimilar circumstances. We must, therefore, carefully observe and study all modifications of the coercitive force, which present themselves when we vary either the chemical or the physical conditions of our experiments, if we would seek to dispel the obscurity in which this undeveloped portion of electro-dynamical science is now involved.

§ 153. Since, by combination with oxygen or carbon, iron acquires the power of permanently exerting magnetic force, it may readily be supposed that chemical compounds will be acted upon differently from the elements which compose them. And we have already seen (§ 128) that brass is, in some instances, susceptible of magnetism, though the copper and zinc of which it is formed are insensible to its influence.

M. Gay-Lussac found that union with phosphorus, arsenic, or tin, enables iron to retain magnetism permanently, unless the proportion of these substances exceed a certain limit, in which case they render the compound totally insusceptible of magnetism. And similar results were obtained by *Mr. Hatchett*, with reference to combinations with sulphur, phosphorus, &c.

On the other hand, *Mr. Chenevix* observed that arsenic, in very small quantity, deprives nickel of the power of acquiring magnetic properties. And *Dr. Seebeck* even recommends an alloy of two parts of copper with one of nickel, for the manufacture of compasses, as entirely insensible to magnetism. Also, *Dr. Young* found that mere traces of antimony destroy the polarity of iron; and *Dr. Seebeck* could detect no action exerted upon a delicate needle by an alloy of one part of iron and four of antimony, even when in rotation.

This subject, however, requires further investigation, before our knowledge of it can be deemed other than most imperfect.

§ 154. The coercitive force of steel depends not only upon the particular kind, but also upon its temper; thus, soft steel retains but little more magnetism than malleable iron, while hardened steel is magnetized with difficulty, but permanently. According to *Dr. Robison*, steel tempered to the blue color, or that degree which renders it fit for watch-springs, readily acquires intense magnetism, which at first dissipates very rapidly, but afterwards slowly, until it finally becomes constant and equal to about one-third of its original intensity. As the coercitive force has been found to be proportional to the temper, it follows that steel made as hard as possible offers a maximum resistance to the acquisition of magnetism, and retains it most perfectly. For the construction of artificial magnets, we must therefore, in each instance, be governed in our selection of the suitable degree of temper, as much by the practical efficiency of the methods we may employ for magnetizing, as by the intensity of magnetic power we desire the magnet permanently to possess. Also, since highly tempered steel is extremely brittle, consideration should be had to the probable circumstances under which the magnet will be used, that the temper given to it may be such as not to render it very liable to accidental fracture.

§ 155. Heat seems to exert two distinct effects upon magnetic development in iron and steel: one tending to diminish the coercitive force of the metal, the other affecting its susceptibility of magnetic induction, or the magnetism itself.

It has long been known, and was observed by *Dr. Gilbert*, that when a magnet is heated to a bright-red heat, it loses its properties entirely, and is found to be inactive when it becomes cool. *Coulomb* subsequently ascertained, by the method of oscillations, that this loss of magnetism takes place progressively, commencing even at low temperatures.

When heated to a white heat, iron and steel not only lose all magnetic properties which they may have possessed, but also become perfectly inert, so that they can neither act upon, nor be attracted by magnets. At a blood-red heat, however, *Mr. Barlow* has shown that the magnetic susceptibility of all kinds of iron and steel is at a maximum. Also, he found that between this maximum and the zero state, which occurs at a white heat, an anomalous change of polarity generally takes place; by which the end of the heated bar, which at blood-red heat acts *positively*, or as the north pole of a magnet, gradually ceases to act, and then acquires a *negative* polarity, or that of a south pole. A singular fact, which may not improbably be connected in some manner with the *diamagnetic* phenomena lately observed by *Faraday*.

The magnetic power of soft iron was found both by *M. Kupffer* and *Mr. Christie*, to increase with the temperature: an effect the reverse of that produced by heat upon steel magnets. *Mr. Christie* also observed that equal increments of temperature do not cause equal decrements of magnetism in steel, and that the greater portion of the whole effect is

produced instantaneously, indicating that the distribution of magnetism is superficial (see § 85).

The general conclusions which may be deduced from the above facts are, 1st, that heat, by overcoming the coercitive force of ferruginous bodies, favors the production of temporary inductive effects, and tends to destroy permanent magnetism; 2d, that while it acts thus indirectly by changing the state of the metal, it tends directly to weaken the magnetic force itself.

§ 156. The coercitive force of steel is also affected by mechanical action, and especially by such blows and jars as will make it vibrate with a ringing sound. These vibrations seem to interfere with the peculiar molecular state to which the coercitive force is due, and thus co-operate with external disturbing forces in causing magnetic polarity, and with internal actions in destroying it when once developed.

Hence, in handling magnets it is important that care should be taken to avoid letting them fall, or knocking them against any thing. For the same reason hammering, filing, twisting, etc., aid in developing magnetism in iron or steel, under the inductive influence of the earth's magnetism.

§ 157. *Methods of making Magnets.* The method first employed for making artificial magnets, is known as that of *simple touching*; it is performed by rubbing the entire length of the steel bar to be magnetized, with the end of a magnet or loadstone: care being taken to rub it only in one direction.

§ 158. In 1745, Dr. Knight invented a method which was at the time a great improvement. Two bar-magnets are held obliquely and placed with their opposite poles close together, upon the middle of the steel bar; both magnets are then drawn backwards upon the bar, and this operation is often repeated.

The superiority of this method over the former is evidently owing to the more intense inductive effects produced by the conspiring action of the opposite poles of the magnets.

§ 159. The next method invented, was that of Duhamel. A parallelogram is formed of two steel bars connected by two short bars of soft iron; and each of the steel bars is then rubbed in the same manner, as in Knight's method; but with two bundles of magnets instead of with single magnets only.

This method is much superior to Knight's, by reason of the reaction of the induced magnetism of the soft iron bars or armatures, and the greater power of a number of magnets when combined, than of two alone.

§ 160. In the method known as that of *Æpinus*, the bars are arranged as in the method of Duhamel; but steel magnets are substituted for the soft iron armatures, which form the ends of the parallelogram. Each of the bars is then rubbed backwards and forwards with the opposite poles of two magnets, separated by a small piece of cork, and inclined so as to form an angle of 140° with each other, and angles of 20° with the bar to be magnetized.

§ 161. The method of *double touch*, as it is called, was invented by Mitchell; the steel

bars to be magnetized are placed end to end in a straight line, and then rubbed with a horse-shoe magnet, or with the opposite poles of two powerful bar-magnets, slightly separated from each other. It is preferable to arrange the bars in the form of a parallelogram, as in the methods of Duhamel and *Æpinus*, so as to constitute a closed circuit. And care must be taken not to reverse the direction of the magnetizing forces, by changing the relative position and motion of the poles of the horse-shoe magnet, as well as to put the lifter on before breaking contact between the magnet and bar.

The method of *double touch* derives its name from the circumstance, that two opposite poles are made to act together upon successive portions of a bar. It is evidently in conformity with the molecular distribution of magnetism assumed in the theory of Coulomb. But its great superiority depends upon the fact, that the inductive action of a horse-shoe magnet upon a body between its poles, is equal to the sum of their respective actions, while upon a body beyond either pole, the action is only equal to the difference of those actions.

The great defect of this method, which is used chiefly for making magnets of considerable energy, is its liability to produce *consecutive poles*, or such an irregular distribution of magnetism as to constitute rather a number of colligated magnets, than a single one with only two poles. To this defect, however, all the methods above mentioned are more or less subject; and it is, indeed, a difficult matter to make very large magnets free from consecutive poles, and charged to saturation.

§ 162. The late Mr. Isaiah Lukens, of Philadelphia, employed a method for making horse-shoe magnets which was remarkably efficient, and which, as he saw fit to keep it secret during his lifetime, has never, to our knowledge, been published.

The circuit formed of the steel horse-shoe to be magnetized, and its soft iron lifter, is well rubbed, according to the method of double touch, with a powerful horse-shoe magnet, carrying it completely round the circuit, and always in the same direction; after which the active magnet is removed in the following manner:—its two legs are made to straddle the arch of the horse-shoe, and then to slide evenly down the legs of the latter until it comes upon the iron lifter; in this position its own armature is properly adapted to it, and contact with the former is then gently broken.

The distinctive feature of this method is the method of removing the active magnet, when it has developed the latent magnetism of the closed circuit. It may be regarded as a combination of the method of double touch with that of single touch; and much of its superior efficiency is doubtless owing to the circumstance (see § 111), that both the active magnet and the steel horse-shoe, with its iron lifter, form very perfect closed circuits.

§ 163. The best method of making powerful magnets is, however, that of Prof. Henry, by electro-magnetic induction. The coercitive power of the steel bar being overcome by heating it to redness, it is plunged into a cylin-

drical vessel of cold water, around which a powerful galvanic current is passing through a wire helix. The intense development of magnetism which takes place in the heated bar, thus becomes fixed, by the restoration of the coercitive force.

§ 164. *Preservation of Magnets.* As the magnetism of steel bars is permanent only by virtue of the coercitive force, or resistance of the metal, it follows, generally, that any thing which diminishes that resistance or increases the force opposed to it, tends to destroy the polarity and energy of the magnet. This proposition may be stated more clearly by reference to the theory of Coulomb, according to which permanent magnetic development consists in a molecular separation of two hypothetical fluids, the particles of which are in instable equilibrium, being kept apart by the resistance or coercitive force of the steel, and constantly tending to reunite, in obedience to their attraction for each other. If, therefore, a bar of steel be magnetized to saturation, its magnetism will be weakened either by mechanical or physical causes, such as vibration, heat, etc., which affect its molecular state, or by any inductive influence tending to excite in it an opposite polarity. Hence, it is exceedingly injurious to magnets to place their similar poles together, or to subject them long to the influence of the earth's magnetism in positions contrary to those which they naturally assume under its directive action.

Filing, grinding, polishing, or rough treatment of any sort, is found to be very injurious to magnets. Also, oxidation or rust impairs their strength; a fact, which is probably connected with that of the superficial distribution of magnetism.

Since the reaction of induced magnetism renders the inducing magnet stronger (§ 79), it follows that horse-shoe magnets should always be provided with *lifters*, *armatures* or *keepers*, as they are indiscriminately called; and that bar-magnets should be packed in boxes, to avoid mechanical injury, with their poles in opposite directions, and either in contact, or else united by soft iron armatures, so as to form a rectangle.

Terrestrial Magnetism.

§ 165. The security of the immense amount of life and property daily staked, with implicit confidence, upon the indications of the mariner's compass; the general progress of religion, civilization and knowledge, so intimately connected with and dependent upon commerce; and the promotion of science, are considerations which render the investigation of the phenomena of terrestrial magnetism certainly one of the most important to which attention can be given. If the magnetic force of the earth were such as to cause the needle invariably to point due north and south, then the navigator would possess in it an infallible guide. Unfortunately, however, that force varies from place to place and from time to time, according to laws of which we are ignorant; and of this ignorance numerous shipwrecks have been the natural and lamentable consequence.

§ 166. *Geographical variation, or Declination.* That the action of the earth upon the magnetic needle is not confined to particular places, but universal, has been ascertained by numerous observations made by travellers in every accessible portion of the globe. Before experience had fully established this fact, the mariner justly felt fearful lest that property, which alone renders the compass useful, might fail in certain regions. The *declination*, or *geographical variation*, was first observed by Columbus, in 1492, during his celebrated voyage of discovery; in the language of his biographer, Washington Irving, "He perceived, about night-fall, that the needle, instead of pointing to the north star, varied half a point, or between five and six degrees to the north-west, and still more on the following morning. Struck with that circumstance he observed it attentively for three days, and found that the variation increased as he advanced. He at first made no mention of this phenomenon, knowing how ready his people were to take alarm; but it soon attracted the attention of the pilots, and filled them with consternation. It seemed as if the laws of nature were changing, and that they were entering another world, subject to unknown influences. They apprehended that the compass was about to lose its mysterious virtues; and, without this guide, what was to become of them in a vast and trackless ocean?"

§ 167. Before the time of Gilbert, all speculations with reference to the theory of terrestrial magnetic phenomena were vague, and many of them were even perfectly ridiculous. In his celebrated work, the full title of which is, "*de magnete, magneticisque corporibus, et magno magnete tellure*," he attributes them to their true cause, by regarding the earth as a large magnet.

§ 168. That the earth is indeed a magnet, or, in other words, that the forces it exerts upon a needle are magnetic, is proved by the following well-established facts:—

1. Ferruginous bodies become magnetic by induction, in the direction which a needle assumes, by virtue of the earth's action. Thus, if a bar of soft iron be held in that direction, the end turned to the north will acquire a polarity similar to that of the north pole of a steel magnet; and, if the bar be turned end for end, its polarity will be reversed. By reason of this inductive action, bars of iron, which are placed in vertical positions, such as pokers, tongs, balustrades, etc., exhibit magnetic polarity.

2. The directive force which at any place attracts the north pole of a needle, repels its south pole with equal intensity, if the two ends of the needle are magnetized to the same degree.

3. Electro-dynamical coils and cylinders are affected by artificial magnets and by the directive force of the earth (§ 97), in the same manner. And a terminated electric current (§ 73, Case 3) revolves under the influence of the earth's magnetism, as under that of an indefinite current.

§ 169. The distribution of the magnetism of the earth is not symmetrical; its magnetic

poles do not coincide with those of the axis of revolution, and the magnetic equator is an irregular curve, with numerous flexures, the general inclination of which is such as to form an angle of about 12° with the plane of the equinoctial.

If a small needle, suspended horizontally at its centre by a thread and free to turn about its point of suspension in every direction, be moved directly over a bar-magnet, from end to end, the needle will evidently assume positions of equilibrium, which will all lie in the vertical plane passing through the axis of the magnet; but the horizontal position of the needle will be preserved only when it is over the middle of the bar; towards either end, it will *dip*, or form an angle with the bar, of greater magnitude as it recedes from the middle point, by virtue of the more powerful action of the nearer pole. And if, in this experiment, we substitute for the bar-magnet one which is spheroidal, and in which the distribution is irregular; then, if a magnetic needle be moved over its surface, it will form a greater angle with a tangential plane, or *dip* more and more, as we move it from the equinoctial to the polar positions; and the direction of the normal plane or *magnetic meridian*, in which it will assume its position of equilibrium at any point, will be determined by the resultant of all the magnetic forces of the spheroid. Such an experiment would illustrate roughly not only the principal phenomena of the earth's magnetism, but also the method which is usually employed in their study.

§ 170. To determine a force, we must know its point of application, its direction and its intensity. For a complete knowledge of the earth's magnetic forces, these data must therefore be accurately observed, at places and times sufficiently numerous to establish a series of results, which may be interpolated and extended without appreciable error.

§ 171. The points of application of terrestrial magnetic forces are known when we have the latitudes and longitudes of the places of observation, which are found by methods given in treatises on practical astronomy. The direction of the force at any place is determined by its *declination* and *dip*, as they are usually called, or the angles which are formed, respectively, by the *magnetic meridian* with the true or astronomical meridian, and by the force itself with the horizontal line situated in the magnetic meridian.

To measure these angles accurately, we must employ delicate and nicely-constructed instruments, and carefully eliminate errors of observation or workmanship. By means of a mirror fixed vertically on the needle of Coulomb's balance, and reflecting the divisions of a distant graduated scale, observed with a fixed telescope that the observer may be removed from the needle, Prof. Gauss has succeeded in rendering the slightest changes in the declination or intensity of the magnetic force sensible, as well as free from mechanical and other disturbances, which often happen in observing at close distances: and he has thus given to magnetic observations a degree of exactness equal to that of modern astro-

nomical measurements. For descriptions of the *variation compass* and of the *dipping needle*, as well as of the instruments of Gauss and the manner of using each, the reader is referred to works on magnetism, which are more complete than the limits of this article permit it to be.

§ 172. To ascertain the *intensity* at different places, the times of oscillation of the same needle, delicately suspended, as in the balance of Coulomb, evidently give, (§ 18,)

$$t^2 : t'^2 :: g' : g;$$

or the forces inversely proportional to the squares of the times of oscillation. The force, however, by which a needle thus suspended tends to return to the magnetic meridian, is the horizontal component of the whole magnetic force acting upon it; if, therefore, we denote the latter by f and the dip by v , we have

$$g = f \cos v$$

as the equation, from which we obtain the whole intensity from that of the horizontal force.

A very important improvement in this method of oscillations, has been made by Prof. A. D. Bache; by vibrating the needle in a vacuum, he eliminates the errors which arise from variations of atmospheric resistance.

Professor Gauss has given a valuable and ingenious method for determining the absolute intensity of the earth's magnetic force, at any place and time, independently of the variable magnetism of the particular needle employed. This method cannot be fully explained in an article so brief as this; it, however, depends upon the artifice of employing a second magnetic needle to determine, by vibrations at various distances, the ratio of the earth's force to that of the first needle; and having ascertained, by the method of oscillations, the combined action, or product, of the same forces, he has, therefore, two equations from which, by eliminating the force of the needle, he obtains the terrestrial magnetic intensity, independent of all instrumental relations.

§ 173. *Local Variation.* In magnetic observations, errors are often produced by the proximity of ferruginous bodies or other accidental disturbing influences. To such effects the term *local variation* is usually applied; and too much care cannot be taken to prevent deviations arising from this source. On shipboard, and especially upon steamers and vessels of war, the large masses of iron contained in their machinery, guns, &c., always give rise to local variation, the amount of which will of course vary in different ships, but is usually quite considerable, as appears from the following table of observed deviations, compiled by Prof. Barlow from authentic sources:

Ship.	Observer.	Place.	Local Var
Conway.....	Capt. Hall	Portsmouth ..	$4^\circ 32'$
Leven.....	" Owen	Northfleet... ..	$6^\circ 9'$
Barracouta..	" Cutfield....	do.	$14^\circ 30'$
Hecla.....	" Parry	do.	$7^\circ 27'$
Fury.....	" Hopier.....	do.	$6^\circ 22'$
Griper.....	" Clavering...Nore		$13^\circ 36'$
Adventure ..	" King.....	Plymouth	$7^\circ 48'$
Gloucester ..	" Stuart	Channel.....	$9^\circ 30'$

The last of these ships was reported as having been "invariably drawn, in consequence of this deviation, to the southward of her intended place, notwithstanding the greatest care being taken in steering her." The lateral errors which, in sailing ten miles, would occur in consequence of local variations of 5° , 10° and 15° , amount respectively in miles to 0.87, 1.74, 2.59, nearly. From such errors it is evident that the most disastrous consequences may often arise; and Mr. Barlow has shown that many shipwrecks may be justly ascribed to this cause.

§ 174. The following ingenious method of correction for local variation was invented by Mr. Barlow. The ship's compass is carefully compared in every position of the vessel with one on shore removed from the action of all disturbing forces; when the deviation caused by the ship's iron has thus been carefully ascertained, its compass is taken on shore, and a *compensating plate* of iron is attached to the box in such a position as to produce an effect precisely similar to the local variation. This plate, which is connected with the compass in such a manner that it may be detached at pleasure, is then removed from it, and the compass is restored to its place in the ship. Whenever the compensating plate is used on board the vessel, its action, being exactly like the local variation both in direction and intensity, doubles the latter, and the deflection produced by the plate is therefore the correction to be applied; thus, if the ship's course were found to be $N. 45^\circ W.$ by the compass alone, and afterwards $N. 50^\circ W.$ with the compensating plate attached, 5° is the quantity by which the ship's iron augments the true reading, and $N. 40^\circ W.$ is therefore the true course.

§ 175. Another, but less accurate mode of determining the local variation of a ship is by comparing the compass in the binnacle with a standard compass fixed in some other part of the vessel, where it will be least affected, as, for instance, at the main-mast head.

As the action of a ship's iron is due to the inductive influence of the earth's magnetism, operating parallel to the line of the *dip*, and upon every particle of iron in the ship; it is evident that the resultant will be equivalent to the action of a single magnet, placed, if the iron be distributed uniformly on both sides of the vessel, somewhere in the vertical plane of the ship, with its south pole upwards in northern latitudes, and its axis in the line of *dip*. Hence, if the course be in the direction of the magnetic meridian, no deflection of the compass-needle will be produced by the iron. But if it be inclined to that meridian, the iron will act attractively upon the north pole of the needle, and repulsively upon its south pole (§ 88), producing deflections which, when the course is easterly, are equal in extent, but opposite in direction, to those which take place when it is westerly; and which attain a maximum when the vessel sails due east or west.

From the above it is evident, that if the iron of the ship be distributed symmetrically with reference to both its length and breadth, a compass placed at the bow and one in the bin-

nacle, or at the stern, will be equally and oppositely deflected.

§ 176. *Secular Variation.* This term is usually applied to a slow, progressive change of declination, which from year to year occurs at any one place. Thus, for instance, at Paris the observed position of the magnetic meridian was, in the year 1580, about $11^\circ 30'$ east; in 1660, nearly zero, or *no variation*; then, becoming west, the declination gradually attained a maximum value, at London, in 1818, of $24^\circ 30'$, and at Paris, in 1819, of $22^\circ 29'$; and it has since been retrograde, or decreasing. At New York the declination, in 1609, was 13° west; it gradually decreased until 1800, when it amounted to about 4° , and has since increased, being at present nearly $5\frac{1}{2}^\circ$. If a line be drawn from the north-west angle of the State of Pennsylvania to Cape Look-out, in North Carolina, it will pass through those places in the United States where the magnetic needle points to the true north, or will be a *line of no variation*. To the east of this line the declination is west and increasing, and to the west of it is east and decreasing,—which is equivalent to a westward motion of the line itself. Prior to 1800, however, the observed changes were in the opposite direction, or the line of no variation was moving to the east.

§ 177. From the above it is evident, that if a chart of magnetic variation be constructed by means of actual observed declinations made at any one epoch over the entire globe, it will, after a few years, cease to be of service to navigators. Nor, unless we know the general law of the *secular variation* for every place on the earth's surface, is it possible to apply to such a chart the corrections requisite to determine existing from previous declinations. To ascertain this law, of which we are yet ignorant, is therefore a matter of the highest importance.

§ 178. Of late years, at the suggestion of the celebrated traveller Humboldt, who himself made many valuable magnetic observations during his travels, a grand combined effort has been made to discover the laws of terrestrial magnetism, by means of frequent and simultaneous observations, prosecuted upon a uniform system in numerous observatories scattered over the world. Most of these observatories are devoted exclusively to magnetic researches, and have been established by government patronage; some of them, however, are supported by private munificence; and they have all been furnished with excellent instruments for determining the declination, the *dip*, and the intensity. In this enterprise Russia and England have been the most liberal, though other nations have generally co-operated, in proportion to their extent of territory and power; our own government, however, has not contributed its proper share towards this object, than which nothing can be more important to navigation.

Besides the establishment of observatories, an expedition to the South Polar Sea, under Sir James Ross, and another to the North Polar regions, under Sir John Franklin, were fitted out by the British government, with the

view of making magnetic observations. The previous expeditions under Parry, Back and others, in search of a north-west passage, as well as those of Russia and France, and that of our own country, under Capt. Wilkes, will likewise furnish valuable data for these magnetic investigations.

Magnetic surveys of extensive districts have also been made in America, Europe, Africa and Asia, at the expense either of individuals or of governments, and designed to determine the direction and intensity of the magnetic force, in various places.

§ 179. To reduce and discuss the mass of observations, amounting to several millions, made at all the different observatories, as well as by various voyagers and other persons, will certainly be a work of immense labor; but we may confidently expect much valuable information to be the result, though the principal laws of terrestrial magnetism may remain undiscovered. To determine these laws exactly, will require a considerable number of years; for accurate observations have not been made in many places, until recently; and the correct interpolation of a series from a few scattered and roughly measured values, is an impracticability. Even such values may, however, give approximate and useful knowledge.

§ 180. *Annual Variation.* Besides the secular variation, the declination is subject to both an *annual* and a *daily* variation, at every place. The annual variation was first observed by Cassini, in 1786, at Paris, who found the change of declination retrograde from the vernal equinox to the summer solstice, and direct during the rest of the year. This result was confirmed by observations made at London, from 1795 to 1805, by Gilpin; but the difference was 9' at Paris in 1786, and less than a minute in 1800, at London. From 1817 to 1819, at the maximum westerly declination, according to the observations of Col. Beaufoy, there was no annual variation. While at Salem, in Massachusetts, the observations of Dr. Bowditch, in 1810, indicate a direct variation from April to August, and a compensating retrograde motion during the autumn.

Hence, it appears that the annual variation differs from place to place in the northern hemisphere, and at the same place from year to year. Also, that it is probably dependent upon the secular variation, as well as the earth's position in its orbit. The observations now in progress will doubtless furnish many facts concerning this variation, of which it is evident that we at present know almost nothing.

§ 181. *Daily Variation.* The daily change in the declination was first observed and studied by Graham, in 1722; who concluded from his observations, that during the forenoon the north pole of the needle moves to the west, but returns to its first position in the evening, and remains nearly stationary during the night. Recent observations show that there are two *maxima* and two *minima* in the daily variation; or that it consists of two oscillations, one occurring during the day, and the other at night, which is similar to the former, but of smaller magnitude. The extent of this variation is

about twice as great in summer as in winter. It changes with the latitude, increasing as we recede from the magnetic equator, where it is nothing. In the southern magnetic hemisphere, the direction of the daily variation is opposite to that which it follows in the northern.

§ 182. *Variations of the Dip and Intensity.* We have already mentioned (§ 169), that the dip varies from the magnetic equator, where it is zero, to the magnetic poles, at which it becomes 90°. An analogous change occurs in the intensity, which, if that at the magnetic equator be assumed as unity, is comprised within the limits of 1 and 2 nearly, on the North American continent. Lines of equal dip are not parallel to those of equal intensity; and their respective poles do not, therefore, coincide: according to the observations of Capt. Ross, the dip is 90°, or vertical, in lat. 70° 5' N., and long. 96° 46' W., in Boothia Felix; while the magnetic survey of Capt. Lefroy shows, that the isodynamical line of 1.875 is an ellipse, 580 miles long and 220 broad, with its centre in lat. 52° 19' 3" N. and long. 91° 59' W., near the head of the Albany river in Canada, where the intensity is 1.88; the major axis of the ellipse being inclined 57° 50' to the parallel of geographic latitude. Besides these geographical changes in the dip and intensity, they are subject, like the declination, to secular, annual and daily variation, according to laws which have not yet been ascertained; the dip, for instance, at London, was 74° 42' in 1720, and 69° 38' in 1830; similarly, at Paris, it was 75° 0' in 1671, and 68° 0' in 1825; having constantly decreased at both these places.

§ 183. The line of *no dip*, or the magnetic equator, experiences a secular variation, and has moved from east to west through an angle of 10°, between 1780 and 1825, as appears from its position at the former epoch, deduced both by Hansteen and Morlet, from observations made by Capts. Cook, Vancouver, and others, when compared with that which it occupied at the latter epoch, determined by Capt. Duperrey from his own observations, and those of Capt. Sabine and M. de Blosseville. Humboldt has also shown that a progressive or secular change of the dip is a necessary consequence of this motion of the magnetic equator.

§ 184. *Fifful Variation.* During the occurrence of an aurora borealis, the magnetic needle is disturbed in a remarkable manner, being often deflected several degrees to the east or west, not steadily, but by sudden fits or intermitting impulses, which give it a very irregular motion. Of the physical cause of this peculiar disturbance, which has been called the *fitful variation*, we know only that it is connected with a mysterious meteorological phenomenon, which, from its appearance, we believe to be electrical, but cannot refer to any satisfactory hypothesis.

It has been found, by observations made at the American observatories, as well as by those at Munich, that the fitful variation is in a measure dependent upon the hour of the day, or the sun's position; the easterly perturbations having a maximum, both in fre-

quency and intensity, in the evening, and the westerly in the morning, while both have a minimum in the afternoon.

§ 185. *Perturbations.* A remarkable accordance, in time and direction, of the perturbations of the earth's magnetic force observed at different places, has been disclosed by observations made in the magnetic observatories. From which it appears, that the magnetism of the earth is in a constant state of oscillation, and that the observed perturbations occur at the same instant of time, at places remote from each other. Thus, for instance, observations of the declination made at Göttingen, were graphically compared with similar and simultaneous observations made at Berlin and other places in Europe, the observed results at each being represented by the ordinates of a curve, of which the abscissas were the corresponding times; and it was found, when these curves were placed side by side, that their flexures coincided in a striking manner, indicating that like disturbances occurred at the same time, at all the places.

It was interesting to ascertain to what extent, over the earth's surface, the above coincidence of perturbations takes place, and whether they might not even be employed for determining, approximately, differences of longitude between distant countries. For this purpose, observations were made by Prof. A. D. Bache, in Philadelphia, and by Prof. Lloyd, in Dublin; but, though it was found that the needle, if much disturbed in Dublin at any time, was so likewise in America; yet the flexures of the curves no longer corresponded, concavities in the one being frequently opposite to convexities in the other.

The same accordance in time and direction, which was found to exist in perturbations observed in Europe, has, however, been shown to hold good for observations made in America: the magnetic curves of the observatories at Toronto, Philadelphia and Boston, having the same remarkable similarity. Hence, it appears that this result is general for large districts of territory, though not for the entire northern hemisphere.

§ 186. *Theory of the Earth's magnetism.* Various hypotheses have been, from time to time, brought forward, to account for the phenomena of the earth's magnetism; but of them all it may be said, that we have not yet attained to a sufficient knowledge of facts by observation, to justify us in making extended generalizations. Of the curve, which would represent the law of any series of similar results, we know only a point here and there, and are unable to draw its intermediate path.

Dr. Gilbert attempted to refer the observed facts to the action of a hypothetical bar-magnet, having its two poles or ends placed near to those of the earth's axis; but M. Biot proved that the observed directions and intensities at various places over the earth would, according to Gilbert's theory of two poles, be the better represented the nearer these poles were supposed to approach each other, or if they both coincided at the centre of the earth.

Halley, and more recently Hansteen, assumed that the earth has four magnetic poles,

two in the Western, and two in the Eastern hemisphere; but even this hypothesis is insufficient, and must be connected with that of the revolution of the poles, in different periods, in order to explain the phenomena of variation.

Lastly, Mr. Barlow attempted to deduce the positions of the magnetic poles, from the directions and intensities observed at different places; but found that he obtained the most discordant results, or that every place indicated different magnetic poles. This conclusion tends to show that the magnetic poles of the earth are rather regions having a diffused and variable magnetic distribution, than particular points; and it seems to be confirmed by subsequent observations.

§ 187. Physical theories of the earth's magnetism have usually been rather of the nature of vague speculations, than scientific hypotheses. While some have referred it to the action of magnetic metals in the globe itself, others have been led by such phenomena, as the influence of the aurora borealis and the falling of meteoric bodies (usually metallic, and composed of iron, nickel, &c.), to regard the atmosphere as the magnetic region, by reason of ferruginous and other metallic matter contained in it.

We have seen, however, that the annual, daily and fitful variations seem to be intimately connected with, or dependent upon the sun's action. And there is also a singular connection between the mean temperature and magnetic force at every place, which tends to show that they are probably common effects of the same physical cause. The nature of this connection may be thus expressed: the *isothermal lines* of the earth correspond with its *isodynamical magnetic lines*; or, in other words, imaginary lines drawn through places having the same mean temperature, will coincide with lines passing through places at which the magnetic force is of the same intensity: a fact discovered by Sir David Brewster, and confirmed by Capt. Duperrey.

§ 188. As the theory of Ampère has served to connect and explain so many magnetic phenomena, we naturally expect that it should throw light upon the subject of terrestrial magnetism. According to that theory, the earth should be a large electro-dynamical sphere, with currents passing round it in the direction of the sun's apparent motion, or opposite to the earth's real motion. We have already seen (§ 168), that these views are confirmed, by the substitution of the earth's magnetic action for that of an artificial magnet in the production of electro-magnetic rotation; and by the fact that currents are acted upon directly by the magnetic force of the earth (§ 97), and by each other in precisely the same manner.

But that Ampère's theory may be used successfully, to account for the phenomena of terrestrial magnetism, has been rendered in the highest degree probable, by a beautiful and ingenious experiment of Prof. Barlow. He took a hollow globe of wood, 16 inches in diameter, and turned parallel grooves, $4\frac{1}{2}^{\circ}$ apart, around it; in these grooves he wound a copper wire, and then pasted over the globe

a map of the world, in such a manner that the poles of the parallel wires corresponded with the probable positions of the magnetic poles, and the equatorial wire with the magnetic equator. A galvanic current was then passed through the wire in the direction required by the theory of Ampère, and a small magnetic needle suspended horizontally by a thread, was brought successively over various parts of the globe; at every geographical position, it assumed a direction which corresponded with the observed declination and dip, and thus gave a correct representation of the earth's magnetism.

§ 189. To render the explanation of terrestrial magnetism, by means of the electro-dynamical theory, complete, it is only requisite, therefore, that we should be able to establish the probable existence of electric currents flowing constantly around the earth, by reason of some adequate physical cause, operating according to well-known laws. The remarkable coincidence of the isothermal with the isodynamical magnetic lines clearly indicates, that we must look to the sun's action as a powerfully modifying, if not the only efficient and generating, cause of the earth's magnetism. That electrical currents are produced, by subjecting different parts of a conducting circuit to unequal temperatures, has been fully established, by facts which properly belong to, and will be treated of under, the head of THERMO-ELECTRICITY, in the next general division of our subject. Yet, in the present state of our knowledge, we cannot, it must be confessed, show clearly how thermo-electric lines, parallel to the magnetic equator, would be produced by the sun's action; though the very different temperatures at the poles and between the tropics, and the daily presentation of each successive meridian to the sun, by the revolution of the earth, constitute real thermo-electrical arrangements, which seem to be the true sources of terrestrial magnetism, by the development of electrical currents. Should this conclusion be established by a careful and sufficiently extended induction, all the observed phenomena will be susceptible of deduction from Ampère's comprehensive theory; which, by revealing the mysteries of the earth's action upon the mariner's compass, will thus have achieved its most glorious triumph.

Thermo-Electricity.

§ 190. *Thermo-electric crystals.* We have already alluded to heat (§ 8), as a source of electrical development; and it appears to have been known, even to the ancients, that the tourmaline acquires attractive properties, when heated. Hence Linnæus gave to that mineral the name *lapis electricus*; and the Dutch, who found it in Ceylon, called it *aschentrikker*, because it attracts ashes when thrown into a fire.

The thermo-electrical properties of the tourmaline were first investigated by Æpinus, in 1756. To each side of a segment cut perpendicularly to the axis, he fitted a metallic disc, to which a conducting wire was soldered; the extremities of the wires were brought near to

each other, and a pith ball was suspended between them. When the tourmaline was heated by plunging it into hot water, and then placed between the discs, the pith ball vibrated rapidly for several hours between the wires, being alternately attracted and repelled by each; thus indicating that the two faces of the mineral were in opposite electrical states. When the two conducting wires were joined by means of a third metallic wire, all motion of the pith-ball ceased, the electricity being freely conducted from one wire to the other; but it commenced to vibrate anew, when the third wire was removed.

Æpinus found that the temperature of boiling water is apparently that which causes the most intense electrical development in the tourmaline; that, if heated to a much higher degree upon burning coals or a hot piece of metal, it indicates, when removed, little or no excitement, until some time has elapsed; and generally that, whenever a tourmaline is heated unequally, the polarity is at first inverted; the end which would have been positively electrified by uniform heating being negative, and, conversely, the other end becoming positive; after a few minutes this state ceases, and no sign of electricity can be observed; finally, the mineral recovers its electrical action, which continues for some hours, and its polarity is then direct, or similar to that developed when the heat is applied uniformly. This irregularity almost always occurs when the mineral is not heated in a fluid, and is rendered more distinct by heating only one end.

§ 191. The thermo-electrical phenomena presented by the tourmaline and other crystallized bodies, were subsequently studied by the Abbé Haüy, with that skill for which he is so justly celebrated. He found that the Brazilian topaz, the boracite (*borate magnésio-calcaire*), the oxide of zinc, and several other minerals, possess the same property as the tourmaline; and that there is a relation between the crystalline form and the thermo-electrical distribution. In his own words, (*Écoles Normales*, t. 6, p. 102,) "one of the summits always has additional facettes produced by a law of decrement, which does not take place at the opposite summit; this is contrary to the analogy of non-electric crystals, the two summits of which are alike in the number of faces. The simpler summit seems also to be that which becomes negative: a fact which serves to indicate, upon inspection, which portion of a tourmaline will be electrified either positively or negatively."

Haüy also observed that, when an electrified tourmaline is broken in such a manner as to detach a small fragment from one of its extremities, this fragment, however short it may be, possesses both a positive and a negative pole, like the whole tourmaline; although the part of the crystal from which it was separated indicated only one electrical state: a fact similar to that which occurs when a magnet is broken (§ 80), and which renders the theory of Æpinus imperfect. When boracite is heated, the simplest variety of which crystallizes in the form of a cube with imperfect edges and four truncated angles, the perfect

angles become negative, and the diagonally opposite truncated angles positive; so that the four diagonals of the cube constitute as many electrical axes. And this phenomenon, Haüy found to hold good for fragmentary or molecular portions of the mineral.

§ 192. He also repeated the experiments of Épinus upon the tourmaline, and found that there are two limits of temperature beyond which it gives no signs of electricity, usually about 10° and 150° Centigrade, varying with the length of the specimen. When heated uniformly between these limits, one end becomes positive and the other negative, and they remain so while the temperature rises; if in this condition the mineral be cooled regularly, an instant arrives at which its polarity ceases, after which it appears again, though inverted, the *plus-minus* state having become *minus-plus*; and it so remains as long as the temperature is variable and descending. Thus, the electrical condition seems to depend upon the variation of the temperature; and at any degree between the limits, the mineral may be either in a natural state, or electrified with direct or inverse polarity, as the temperature may have been either constant, ascending or descending. In some instances, Haüy observed anomalous changes of polarity during the continuous rise or fall of the temperature.

§ 193. To the list of crystallized bodies possessing thermo-electrical properties, Sir D. Brewster has added many others, among which are tartaric acid, citric acid, and cane sugar. And M. Becquerel has shown, that a tourmaline heated or cooled at one end, while the other end is kept at a constant temperature, shows signs of electrical excitement only in one half, the other appearing natural; an anomaly, which he supposes may be owing to an irregular distribution within and upon the surface of the crystal, by which the positive and negative effects mask each other.

Unequal distribution of heat in different directions seems to be the cause of this thermo-electrical excitement in the molecules of crystallized bodies. And as the slightest difference of arrangement or structure in two bodies rubbed together is sufficient to develop electricity (§ 9), it is not improbable, that differences of expansion and consequent mechanical actions among the contingent molecules are the immediate disturbing cause: a view, which renders it possible that mechanical electricity and thermo-electricity are analogous effects of a single cause.

§ 194. *Thermo-electricity of Metals.* In 1822, Dr. Seebeck, of Berlin, discovered that an electrical current is produced, when the equilibrium of temperature is disturbed in a closed circuit, formed of two different metals united by soldering, or by simple contact; the existence and the direction of the current being indicated by its disturbing action upon a delicate magnetic needle. He was, however, unable to obtain from this source currents of sufficient intensity to exhibit the more ordinary effects of electricity, such as sparks, chemical decomposition, etc.

§ 195. By forming thermo-electric circuits of various metals, Dr. Seebeck found that the

current passes from bismuth to any other metal, or that the former always becomes *negative*, as the zinc plate does in ordinary galvanic circles; and also that antimony, on the other hand, becomes *positive* with most of the other metals, or occupies the other extremity of the thermo-electric scale. He also examined the sulphurets, and found that galæna is negative even with bismuth; and that the sulphurets of iron, arsenic and copper, which have a *maximum* of sulphur, occupy places near to bismuth, while all the sulphurets with a *minimum* of sulphur, are at the other end of the scale, and of nearly the same power as antimony.

Various persons have sought to determine the relative positions of the metals in the thermo-electric series, and the following order is that established by the experiments of Prof. Cumming, somewhat extended, and generally confirmed by those of MM. Oersted and Becquerel:

- | | | |
|---------------|-----------------|---------------|
| 1. Galæna, | 10. Titanium, | 19. Iridium, |
| 2. BISMUTH, | 11. Tin, | 20. Zinc, |
| 3. Mercury? | 12. Lead, | 21. Cadmium, |
| 4. Nickel, | 13. Brass, | 22. Charcoal, |
| 5. Platinum, | 14. Copper, | 23. Plumbago, |
| 6. Palladium, | 15. Gold, | 24. Steel, |
| 7. Cobalt, | 16. Silver, | 25. Iron, |
| 8. Uranium, | 17. Molybdenum, | 26. Arsenic, |
| 9. Manganese, | 18. Rhodium, | 27. ANTIMONY. |

In this table, as a general rule, each metal becomes *negative*, or imparts electricity to any one which succeeds; and the more remote in the series any two metals are, the more powerful will be the thermo-electric effects produced by them with each other. This rule has, however, its exceptions; for instance, antimony is more effective with cadmium than with mercury; and iron, if used to form a circuit with either brass, gold, copper, silver, or zinc, causes the deflection of the galvanometer to increase gradually with the temperature, until, at about 600° Fahr., the deviation attains a maximum; after which it decreases as the temperature rises, and at a red heat passes through the zero point, and assumes an opposite direction; indicating that the direction of the electric current which flowed to the iron, is reversed; or that iron, at high temperatures, is negative, relatively to the above-mentioned metals. This anomaly, discovered and investigated by Prof. Cumming, was found not to occur with a circuit of iron and platinum. Other exceptions have been observed, but instead of enumerating them, we refer the reader to complete treatises.

§ 196. With the view of increasing the intensity, Dr. Seebeck attempted to form a compound thermo-electric circuit, analogous to the Voltaic pile or battery; but his researches were interrupted, and the subject was investigated by MM. Fourier and Oersted. By soldering together alternate bars of bismuth and antimony, they formed a hexagonal circuit of three elements; the deviation produced by two active elements was greater than that caused by one, and the effect of three exceeded that of two; a deviation of 60°, the maximum result, was produced by heating three alternate angles of the hexagon, and cooling the other three with ice.

When the number of consecutive elements in the circuit was increased, with the view of augmenting the intensity, they found that the total deviation of the needle was not equal to the sum of the deviations produced by the separate elements; and though each element added to the combined effect, the resistance seemed to increase very rapidly as the length of the circuit was extended; in consequence of which, the maximum effect seemed to be produced by a limited number of elements. Hence MM. Oersted and Fourier concluded, that the intensity of thermo-electric currents cannot be indefinitely increased by multiplying the number of elements; and they proved that such currents are of very feeble intensity, by the fact that, when a pile of twenty elements was used, a short platinum wire transmitted $\frac{1}{40}$ th only of the original current; and the thinnest stratum of an acid, alkaline or saline solution arrested it entirely. They were unable to produce chemical effects; and a slight palpitation of the muscles of a frog was the only indication obtained of the increased power of a compound circuit, besides those shown by the galvanometer.

§ 197. By modifying the arrangement and size of the elements, MM. Nobili and Melloni greatly improved the compound thermo-electric battery, and rendered it capable of producing much greater effects. The elements in their pile are small bars, soldered together at the ends in a zig-zag series, like the parts of the letter W, and insulated intermediately by some non-conducting substance; so as to form a bundle which may be heated at one end, while the other remains cool.

§ 198. With a pile of 120 elements of platinum and iron wire, each one inch long and 0.01 inch thick, wound spirally upon a stick, so that alternate junctions were on opposite sides, Prof. Botto, of Turin, decomposed water; and the Chevalier Antinori subsequently obtained a thermo-electric spark. These results were confirmed by MM. Linari and Wheatstone; the former of whom employed a pile of 25 elements, and an electro-dynamical spiral 505 feet long, aided by the reaction of an electro-magnet of soft iron; with which he obtained brilliant sparks, decomposed water and the nitrate of silver, and magnetized steel needles. While Prof. Wheatstone used a pile of 33 elements, forming a bundle $1\frac{1}{2}$ inch long and three-fourth's of an inch in diameter; which, with one of Henry's ribbon coils, 50 feet long and $1\frac{1}{2}$ inches broad (§ 61), gave a very bright spark.

Mr. Watkins has shown that the thermo-electric pile gives much brighter sparks with Henry's ribbon coil, than with wire helices; and that such a coil, 90 feet long, with a pile of 15 to 30 elements, readily decomposes water, and induces secondary currents in a wire helix, 1500 feet long, capable of giving powerful shocks. A soft iron horse-shoe, which he rendered magnetic by the thermo-electric current, supported 98 pounds.

§ 199. By reason of the general principle that action is always accompanied by equal reaction, it may be inferred from the researches of Dr. Seebeck, that magnets must act simi-

larly upon thermo-electric and galvanic currents. That such is the fact was shown experimentally by Prof. Cumming, by means of a toy, exhibiting the rotation of a thermo-electric current under the influence of a magnet, and of which Marsh's "moving rectangle" is a very ingenious and pretty modification. (See § 94.)

§ 200. M. Pouillet endeavored to ascertain the relative intensities of thermo-electric and galvanic currents, by transmitting them, in opposite directions, through wires of such lengths and diameters as to cause their electro-motive forces to be in equilibrium with, or annul, each other. He thus found, that the current of a galvanic battery of 12 elements, was resisted by a platinum wire, 0.006 of an inch thick and 590 feet long, to such a degree as to be equivalent to the thermo-electric current of one element of bismuth and antimony, excited by a difference of temperature of 76° Fahr., and transmitted by a copper wire 66 feet long and 0.04 of an inch in diameter. And he thence deduced the conclusion, that the intensity of the galvanic current is 114,000 times greater than that of a thermo-electric current, produced by a difference of temperatures of 108° Fahr.

§ 201. By a method somewhat analogous to the above, M. Pouillet investigated the relative conductivity of metals for thermo-electric currents, which he found to be nearly in the following ratios, that of mercury being taken as unity: palladium 58, silver 51, gold 40, copper 38, alloyed gold 13 to 7, brass 12 to 9, platinum $8\frac{1}{2}$, steel 8 to 5, iron 7 to $6\frac{1}{2}$. A difference of temperature which produced scarcely any effect upon mercury, was found to reduce the conductivity of iron or steel in a very remarkable degree.

When the electro-motive force of a thermo-electric current remains constant, M. Pouillet found that the intensity varies directly with the conductivity, and inversely with the length of the circuit. In a conducting channel, formed of pieces of wire of different thicknesses, the electro-motive force in consecutive elementary lengths was found to be of equal quantity, and the intensity in the inverse ratio of the sectional area. (See § 54.)

§ 202. From the preceding facts it is obvious that, by heating two different metals at their points of contact, electric currents of great quantity, but of very feeble intensity, are developed, which possess dynamical properties precisely similar to those of galvanic currents. Also, that by arranging thermo-electric elements in a pile or series, the intensity of the current they produce may be almost indefinitely increased, as in compound galvanic circles.

That the thermo-electric current is not due to the contact of dissimilar metals, or to chemical action, was proved by MM. Yelin and Becquerel, who successively studied the circumstances necessary to its development. By riveting one end of a band of metal near to the other, so as to form a ring of any shape, with a projecting end, M. Yelin ascertained that currents were produced in the circuit, whenever the projecting end was heated; and

that inequality of temperature in a single metal is therefore sufficient for thermo-electric excitement. The same result was obtained with various metals. When pieces of various figures were used, the current varied with the figure; and when bars were heated at one end, their opposite sides and ends caused the magnetic needle to move in different directions. These facts were confirmed by the experiments of Mr. Sturgeon, who showed that if a point at the end of a bar is heated, the current proceeds longitudinally from the heated point along one side of the axis, and returns upon the other, accompanied with transverse currents passing in opposite directions, and nearly at right-angles to the longitudinal ones. When one angle of a rectangular plate was heated, the current was in the direction of the diagonal, and returned along the edges.

That thermo-electric phenomena are not caused by a chemical action of the oxygen or moisture of the air upon the metals, was shown by M. Becquerel, by producing the same effects in dry hydrogen. And he also confirmed the conclusion of Yelin, that unequal distribution of heat is the true cause, by forming a circuit of a single wire soldered together at the ends; when any point of this wire, remote from the junction, was heated, no current was produced, as should evidently have been the case by virtue of the symmetry of the arrangement; but when a knot was made in the wire, and heat applied near to it, a current took place.

§ 203. To the researches of M. Becquerel, we are also indebted for the general theoretical principle which connects and satisfactorily explains thermo-electrical phenomena. It may be stated thus: whenever a particle of metal is heated, it receives from the adjoining particles a portion of their natural electricity, leaving them in a negative state. As the heat is conducted from particle to particle, a current is, therefore, excited in the opposite direction.

Hence, if a bar be heated at one end, a current will flow towards it from the other; and, if heated at the middle, currents will flow to that point from each extremity. To the intensity of the current thus established, M. Becquerel gives the name *thermo-electric power*; this power varies with the kind of metal, and increases with the temperature, but according to laws which are not the same for different metals; nor in the same substance do equal increments of temperature of the ordinary thermometer, correspond to equal increments of thermo-electric power.

If two bars of different metals be soldered together, and heated at the point of junction, then the current of the metal which has the greatest thermo-electric power will predominate; and if the bars form a closed circuit, a current will therefore circulate in it, of which the intensity will be equal to the difference of the thermo-electric powers of the two metals.

§ 204. As the development of thermo-electric currents depends upon the propagation of heat from molecule to molecule, it follows that those metals should act most energetically which are the best conductors of heat. But, as the velocity of a current is retarded by the

resistance which it encounters, the relative conducting powers of metals for electricity will also modify their actions. And, as a general result, M. Becquerel states, that any want of homogeneity in chemical composition, density, structure, or external polish, which may modify the transmission of heat through a metallic wire, tends also to change its thermo-electric power. When, for instance, a portion of a closed circuit of iron wire has been heated to redness for some time; if, after it cools, heat be applied near to that portion, a current will almost always take place in the wire, in consequence of the change which has occurred in its texture.

From the preceding facts, it is evident that the thermo-electric power of metals must depend somewhat upon their specific capacities for heat; but the precise nature of this relation has not been ascertained.

According to Dr. Draper, of New York, the energy of the thermo-electric current of two metals is not proportional to the surface of contact, but, on the contrary, greatest when mere points are united.

§ 205. M. Nobili has formed circuits of substances of much inferior conducting power to that of the metals, such as cylinders of porcelain clay, moistened with water. And Prof. Andrews produced currents of considerable energy, by bringing the unequally heated ends of two similar platinum wires into contact with fused salts, having no chemical action upon the wires, such as borax, carbonate of soda, carbonate of potash and glass; similar results were also obtained by interposing mica and other minerals, when strongly heated.

§ 206. A beautiful experiment of M. Peltier, serves to indicate, in a striking manner, the reciprocal relation which exists between heat and electricity. In the immediately preceding sections, we have seen that heat develops electricity, and, in (§ 57), that electric currents are capable of producing powerful heating effects. Hence, M. Peltier was led to seek specific calorific differences correlative to the variations of thermo-electric power in metals. With this purpose he transmitted a galvanic current through a compound bar of bismuth and antimony, soldered end to end; and found, when the current passed from the bismuth to the antimony, that the junction becomes hot; but when the direction of the current is reversed, or from the antimony to the bismuth, cold is produced. And if, in this experiment, the compound bar be laid in melting snow, and a drop of water be placed in a cavity at the point of union, it soon freezes.

§ 207. By far the most important and interesting results, to which investigations of thermo-electric phenomena have led, are the discoveries relative to radiant heat, made by MM. Melloni and Nobili, by means of the thermo-electric pile, combined with a very delicate torsion galvanometer, or *thermo-multiplier* (§ 96), constituting a thermometer of most remarkable delicacy. These discoveries would be foreign to our subject, and the reader is therefore referred, for full information concerning them, to *Taylor's Scientific Memoirs*.

§ 208. Recently, Prof. Henry has made an ingenious and useful combination of the reflecting telescope with the thermo-electric apparatus of Mellni. By placing the end of the pile in the position usually occupied by the eyeglass, he succeeded in rendering sensible differences of radiant heat from small bodies, at the distance of several miles. With this arrangement, variations of temperature produced by different clouds and by different parts of the clear sky, are readily ascertained; and a difference of radiation between the dark spots and other portions of the sun's disc, is distinctly indicated.

Animal Electricity.

§ 209. *Electrical Fishes.* That a species of ray, called the *torpedo*, which abounds in the Mediterranean and upon the south-western coast of Europe, possesses the power of giving benumbing shocks to the hand of a person who touches it, is a fact which was known to the ancients. They were, however, utterly at a loss to account for this peculiar phenomenon; nor was it explained until Muschenbroeck compared it to the action of the Leyden jar, which he had invented.

That the shock of the torpedo is electrical, was first established experimentally by Mr. Walsh, in 1773, who ascertained that it is transmitted by conductors and arrested by non-conductors, and that the two sides of the fish are in opposite electrical states. These results were confirmed by the researches of Dr. John Davy, who also succeeded in producing chemical decomposition and electromagnetic effects. M. de Blainville had previously shown that the torpedo is capable of causing deviations of the galvanometer; and recently MM. Linari and Matteucci have obtained electrical sparks from the same source.

§ 210. According to Dr. Davy, there are two species of the torpedo, the *torpedo oculata* and the *torpedo diversicolor*; though others have classified them in four species. Other fishes are known to possess similar electrical properties: the *silurus electricus*, which lives in the rivers of Africa; the *trichiurus indicus* and the *tetraodon electricus*, which inhabit the Indian ocean; and the *gymnotus electricus*, or electrical eel, found abundantly in South America. Of these, the gymnotus only has been much studied; it was first described in 1677, by Richer, and is much the largest and most interesting of the electrical fishes.

§ 211. Mr. Walsh procured several gymnoti from Surinam, with which he performed experiments like those he had made with the torpedo. And in 1838, Mr. Porter carried to London and deposited in the Adelaide Gallery, a fine specimen of the gymnotus, forty inches long, which lived four years. Experiments were tried with it by Dr. Faraday and others, and all the ordinary effects of electrical currents were readily produced, such as shocks, sparks, chemical decompositions, deviations of the galvanometer, and magnetizing steel needles.

§ 212. The gymnotus employs its electrical power for self-protection, and for the destruction of its prey. The shock resembles

that of a very large battery imperfectly charged; and Dr. Faraday thinks that the medium discharge of the eel he experimented with, could not have been less than that of a Leyden battery of 3500 square inches of coated surface, charged to the highest degree. Two or three such shocks were also given by it in a scarcely sensible interval of time.

The following translation of the account which Humboldt gives of the gymnotus in its natural state, and of the mode of catching it practised by the South American Indians, affords some idea of the power of this remarkable fish:—

“We started, early on the morning of the 19th of March, for the small village of *Rastro de Abajo*, from which the Indians conducted us to a stream, which, in the dry season, forms pools of stagnant water, surrounded by beautiful trees and various odoriferous plants. They told us that they were going to *fish with horses*; a sort of fishing of which we found it difficult to form a conception; but we soon saw our guides returning from the savannah, driving before them some thirty unbroken horses and mules, which they forced into the marsh.

“The unusual noise produced by the tramping of the horses, aroused the gymnoti from their hiding-places, and excited them to combat. These yellowish and livid eels, resembling large aquatic serpents, swim on the surface of the water, and thrust themselves under the bellies of the horses and mules. A struggle between animals of such different organization furnishes a very wild scene. The Indians, with harpoons and long slender reeds, closely encompass the pool; some climb into trees, the branches of which extend horizontally over the water. By their savage yells and long reeds, they prevent the horses from escaping, or reaching the bank of the pool. The eels, stunned with the noise, defend themselves by repeated discharges of their electrical batteries; and for a long while seem to prove victorious. Several horses yield to the violence of the invisible strokes, which they receive on all sides in organs the most essential to life, and sink under the water, paralyzed by the force and frequency of the shocks. Others, with bristling manes and haggard eyes, expressing anguish, rise and seek to fly from the storm which overwhelms them. They are driven back by the Indians into the midst of the water. Yet a few succeed in eluding the active vigilance of the fishermen; these gain the bank, stumbling at every step, and stretch themselves on the sand, exhausted with fatigue, and with limbs benumbed by the electric shocks of the gymnoti.

“In less than five minutes two horses were drowned. The eels, usually five feet long, press themselves against the bellies of the horses, and discharge the whole extent of their electric organs. The heart, the viscera, and the celiac plexus of nerves are all attacked at once. It is therefore natural, that the effects experienced by horses should be more powerful than those produced by the same fish upon

persons, who only touch it at one extremity. The horses probably are not killed, but merely stunned; they are drowned, because the continued strife between the other horses and the gymnoti prevents them from recovering.

"We felt assured that this scene would terminate only with the successive deaths of the animals employed in it; but gradually the impetuosity of the unequal combat ceased, and the exhausted gymnoti dispersed. They require long repose and abundant nourishment, to recover what they have lost in electrical force. The mules and horses appeared less frightened; their manes were no longer erect, and their eyes were less expressive of terror. The gymnoti timidly approached the edge of the marsh, where they were taken with little harpoons attached to long cords. When the cords are thoroughly dry, the Indians experience no shock in raising the fish into the air. In a few minutes we had five large eels, most of which were but slightly wounded. Others were taken towards evening, by the same means.

"The temperature of the waters in which the gymnoti usually live, is from 26° to 27° cent. (80° Fahr., nearly). It is stated that their electric force diminishes in colder water; and it is quite remarkable, as has been observed by a celebrated philosopher, that the animals which are endowed with electro-motive organs capable of producing effects sensible to man, should not be found in the air, but in a fluid which conducts electricity."

§ 213. The anatomical structure of the torpedo and of the gymnotus, was first examined carefully by the celebrated Dr. John Hunter, who speaks of the nervous distribution of their peculiar organs, thus: "The magnitude and number of the nerves bestowed on these organs, in proportion to their size, must, on reflection, appear as extraordinary as the phenomena they afford. Nerves are given to parts either for sensation or for action. Now, if we except the more important senses of seeing, hearing, smelling and tasting, which do not belong to the electric organs, there is no part, even of the most perfect animal, which, in proportion to its size, is so liberally supplied with nerves; nor do the nerves seem necessary for any sensation which can be supposed to belong to the electric organs. And with respect to action, there is no part of any animal with which I am acquainted, however strong and constant its natural actions may be, which has so great a proportion of nerves. If, then, it be probable that these nerves are not necessary for the purposes of sensation or action, may we not conclude that they are subservient to the formation, collection, or management of the electric fluid, especially as it appears evident from Mr. Walsh's experiments, that the will of the animal does absolutely control the electric powers of the body, which must depend upon the energy of the nerves."

§ 214. *Electro-physiology.* When Galvani, in 1789, discovered that muscular contraction is produced by forming a circuit with two different metals and the limbs of a recently killed frog, one of the metals being connected

with the muscle, and the other with its principal nerve, he concluded that the effect was due to a sort of *animal electricity*, developed by vital energy in the nerves, and conducted to the muscular fibres by the metallic channel. This explanation of the phenomenon, analogous to the theory of the Leyden jar, was received with entire satisfaction, except by Volta (§ 43), and, when the researches on electrical fishes, of Walsh and Dr. John Hunter (§§ 209, 213), which were then fresh in the recollection of physiologists, are borne in mind, the theoretical views of Galvani, based upon and sustained by such well-established analogies, certainly appear to have been most natural and probable. To the mind of Volta, however, more familiar with electrical than anatomical ideas, the theory of Galvani seemed to fail; because, it offered no explanation of the fact that two different metals are requisite to produce considerable effects. In answer to this objection, Galvani proved, by experiment, that a single metal is sufficient, though less effective than two, and that contraction may be produced by bringing the nerves and muscular fibres into direct contact, instead of connecting them by a conducting channel.

In the controversy which ensued, in consequence of these conflicting views, it was contended by the followers of Galvani, that, though the communication between the nerves and muscular fibres must be made, either directly or by a conductor of electricity, it does not therefore follow, that galvanic and ordinary electricity are identical, but only that they are analogous in one of their properties. Nor, while they admitted the force of Volta's objection of the unexplained superior efficacy of dissimilar metals, could they, as physiologists, without overwhelming proof, agree to consider ordinary electricity as the agent of muscular contraction, in substitution for that mysterious power, which, in life, the nerves exert, more or less in obedience to the will. Aldini, a nephew of Galvani, produced powerful contractions by bringing warm-blooded into contact with cold-blooded animals, as, for instance, the nerve and muscle of a frog with the bloody neck of a recently slain ox; and he also found that the nerve of one animal acted with the muscle of another. But when Volta, with his pile, produced muscular action and electrical sparks and shocks by the same means, and furnished to science a new and powerful instrument of research, which soon led to numerous and brilliant discoveries, the views of Galvani ceased to be advocated; and electro-physiological investigations were generally abandoned for other and more attractive fields of inquiry.

§ 215. That electricity may really be substituted for vital energy, in the production of various physiological effects, was fully established, in 1816, by the interesting experiments of Dr. Wilson Philip:—

"The eighth pair of nerves, distributed to the stomach and subservient to digestion, were divided by incisions in the necks of several living rabbits. After the operation, the parsley which they ate remained without alteration in their stomachs, and the animals, after

evinced much difficulty in breathing, seemed to die of suffocation. But when, in other rabbits similarly treated, the galvanic power was transmitted along the nerve, below its section, to a disc of silver placed closely in contact with the skin of the animal, opposite to its stomach, no difficulty of breathing occurred. The voltaic action being kept up for twenty-six hours, the rabbits were then killed, and the parsley was found in as perfectly digested a state as that in healthy rabbits fed at the same time; and their stomachs evolved the smell peculiar to that of a rabbit during digestion. These experiments were several times repeated, with similar results."

Dr. Philip obtained like results with dogs; and he was led by analogy to apply the galvanic current, successfully, from the nape of the neck to the pit of the stomach, for the relief of asthma. By numerous experiments, he also proved, that voltaic electricity is capable of carrying on the functions of respiration and digestion; from which he concluded that "galvanism seems capable of performing all the functions of the nervous influence in the animal economy; but, obviously, it cannot excite the functions of animal life, unless when acting on parts endowed with the living principle." The experiments of Dr. Philip were repeated, with confirmatory results, by Dr. Clarke Abel, and by some of the French physiologists.

§ 216. When large animals and powerful batteries are substituted for the frogs and small pieces of metal, employed by Galvani in his first experiments, effects are produced which are very striking. Thus, if the wires of a battery of 100 plates be inserted into the ears of a newly-slaughtered ox, the muscles of the head, if it be removed from the neck, are thrown into violent action; the eyes roll in their sockets, the jaws open and shut, the nostrils dilate, and the whole head seems to express endurance of the most cruel torture. If the body of a horse be subjected to similar treatment, the limbs move convulsively with such force as to require the strength of several men to restrain them.

Among such experiments, those performed by Dr. Ure, upon the body of an executed murderer, are worthy of brief notice. With a battery of 270 pairs of four-inch plates, the current, when passed from the neck to the heel, caused the leg, previously bent, to extend so powerfully as nearly to overturn an assistant. One wire being connected with the phrenic nerve, and the other inserted, in the region of the diaphragm, under the cartilage of the seventh rib, contact was rapidly made and broken, by running the end of the conducting wire along the top of the plates in the last trough. "Full, nay, laborious breathing instantly commenced; the chest heaved and fell; the belly was protruded and again collapsed, with the relaxing and retiring diaphragm."

This action took place without interruption, as long as the electric discharges were continued. One conductor being applied, at the eyebrow, to the supra-orbital nerve, and the other to the heel: "most extraordinary grim-

aces were exhibited every time the electric discharges were made; every muscle in his countenance was simultaneously thrown into fearful action; rage, horror, despair, anguish and ghastly smiles, united their expression in the murderer's face. At this period several of the spectators were forced to leave the apartment from terror or sickness, and one gentleman fainted."

§ 217. Dr. Ure concludes his account of the above experiments, with the following valuable remarks:—

"It is known that cases of death-like lethargy, or suspended animation, from disease and accidents, have occurred, where life has returned after longer interruption of its functions, than in the subject of the preceding experiments. It is probable, when apparent death supervenes from suffocation with noxious gases, etc., and when there is no organic lesion, that a judiciously directed galvanic experiment will, if any thing will, restore the activity of the vital functions. The plans of administering voltaic electricity, hitherto pursued in such cases, are, in my humble apprehension, very defective. No advantage, we perceive, is likely to accrue from passing electric discharges across the chest, directly through the heart and lungs. On the principles so well developed by Dr. Philip, and now illustrated on Clydesdale's body, we should transmit along the channel of the nerves that substitute for nervous influence, or that power which may perchance awaken its dormant faculties. Then, indeed, fair hopes may be formed of deriving extensive benefit from galvanism; and of raising this wonderful agent to its expected rank among the ministers of health and life to man."

§ 218. He also observes,—“It is a matter of primary importance, that, for the purpose of resuscitating dormant irritability of nerves, or contractility of their subordinate muscles, the positive pole must be applied to the former and the negative to the latter.” Which conclusion he bases upon experiments with frogs' legs, showing that the convulsive motions caused by bringing a zinc rod into contact with the crural nerves, and one of silver with the muscles, are much greater than those produced when the order of the metals is reversed.

§ 219. Recently, M. Matteucci, of Tuscany, has made a number of most interesting electrophysiological researches; from which it appears, that the conversion of arterial into venous blood, which Liebig has shown to be a species of combustion and the true source of animal heat, is attended also with the formation of electrical currents. By inserting one end of a conducting wire into an incision transverse to the fibres of a muscle, in a living or recently killed animal, and connecting the other end with the external tendinous expansion, these currents may be shown, by very delicate galvanometers, to circulate from within outwards. Hence living muscular fibres, arterial blood and cellular tissue constitute a galvanic circle, in which the two former, like the zinc and the acid of ordinary arrangements, play the part of electro-motive elements by their chemical reaction, while the latter

performs the office of the copper or conducting plate. Such currents exist in all the tissues, as a necessary consequence of nutrition, but are most sensible in the muscles. Their intensity is in direct proportion to respiration. They do not circulate in living animals in the nerves, or in the muscles as masses, at times of voluntary exertion; and are rendered evident, most readily, by judicious connections between unequally distributed tendinous expansions and muscular fibres. When life ceases, they continue only for a short time, but longer in cold-blooded than in warm-blooded animals. By successively connecting the tendinous expansion of one muscle with the fibres of another, a compound muscular pile or battery may be formed, which will act very distinctly upon the galvanometer; and M. Matteucci has obtained *signs of electro-chemical decomposition*, with such piles.

§ 220. M. Matteucci has also investigated the differences in the excitability of nerves produced by voltaic currents in opposite directions. He confirms and extends the views of Dr. Ure (§ 218); and deduces from his experiments the following general conclusions:

The passage of the electric current through a mixed nerve, produces a variation in the excitability of the nerve, differing essentially in degree, according to the direction of the current through the nerve. This excitability is weakened and ultimately destroyed, more or less rapidly according as the *direct current* (one through the nerve from the centre to the periphery) is more or less intense. On the other hand, by the passage of the same current in the opposite direction, or the *inverse current*, the excitability is preserved and increased.

If the same current be made to act upon a mixed nerve, the contraction which occurs at the first moment of its introduction is very different, according to its direction; the direct current always producing a stronger contraction than the inverse.

When the current ceases, the variations in the excitability produced by its passage disappear more or less rapidly. If the nerve be taken from a living animal, so that its excitability is very great, they last only as long as the current circulates; while, if the nerve has lost some of its excitability, they survive the cessation of the current from one to fifteen seconds.

In the treatment of cases of paralysis, lock-jaw, etc., Matteucci thinks that electrical currents may be used with success; and recommends that the operation should not be kept up long at any time; for paralysis ensues when a current passes through a nerve in one direction for a length of time; though it may usually be promptly removed by reversing the current. The more powerful the current, the shorter, therefore, should be the time of its application. For paralysis of the muscles, he recommends that the current should be directed from the extremities to the centre, and inversely for paralysis of the nerves of sensation.

§ 221. Of the physiological effects of the discharge of a Leyden jar or battery little need be said, for most persons are more or less familiar with them. It is amusing to read

the earlier accounts of the sensation and consequences of trifling shocks. They furnish an instructive lesson of the tendency of the imagination, when excited by wonder and dread, to mislead the mind in its operations, and cause it to substitute absurd conceits and misapprehensions for simple truths. If the stories referred to are to be believed, the most horrible convulsions, excruciating pain, fevers, hæmorrhages and paralyses, were the result of very slight shocks. This disposition of the human mind should be borne in mind, in estimating the probability of testimony with reference to the effects of atmospheric electricity, concerning which most marvellous statements are often made.

Voltaic electricity with inductive coils should always be used for medicinal purposes, instead of mechanical, when shocks are to be given; for the reason that, by varying the distance, etc., the intensity of the shock may be modified at pleasure.

§ 222. *Conclusion.* The plan of this article and its necessarily restricted limits have prevented our giving descriptions of the various apparatus employed for telegraphic purposes, and caused us to pass over, with regret, some of the recent inventions of Dr. Page, Prof. Locke and others, which are very ingenious and worthy of attention.

If, in attentively reading this essay, the reader should find that it presents the theory of electrical phenomena intelligibly and methodically, though in some instances too briefly for complete satisfaction; that we have clearly distinguished facts from opinions and suppositions; that we have adhered uniformly to our plan of treating electricity as part of the science of *pure physics*, and not as belonging to chemistry; that we have abstained from descriptions of apparatus and particular experiments, except in instances where they have been of service in establishing general conclusions; and that we have given much more full accounts of recent researches, than of those which have been long established, and are to be found in every systematic treatise; then the writer will have accomplished every end which he has sought to attain. He is, however, aware that he is far from having been so successful; and he respectfully refers the reader, who would acquire thorough and accurate information, to the various original memoirs of persons who have contributed to electrical science; and to the excellent treatises of M. Becquerel and other French writers, as well as to those of Dr. Roget, in the *Library of Useful Knowledge*, and of Prof. Robison and Sir D. Brewster, in the *Encyclopædia Britannica*.

ELECTRO-CHEMISTRY. The influence which electricity has exerted upon chemical science, demands a special notice of the more important facts embraced in electro-chemistry. For theoretic views, refer to the art. **ELECTRICITY**. It is by means of the decomposing power of the galvanic current, that the elementary character of bodies has been established: *i.e.*, the elements are regarded as undecomposable, because they have not yet been resolved into simpler forms of matter. By

the behavior of the elements to each other under electric action, a series has been established, by arranging the elements from the most electro-negative to the most electro-positive, in which the alkaline metals are the latter, and the metalloidal elements, oxygen, chlorine, &c., are electro-negative. In general, where a compound is resolved by galvanic action into its elements, the more electro-negative body, as oxygen, will be developed at the positive pole of a battery, and the more positive body, as hydrogen or potassium, at the negative pole.

But, although chemists agree in the main on the order of bodies in the series, yet they differ in some of its details, in consequence of the differing behavior of the same elements

when acted upon by different agents. These differences are most striking with the proper metals,—iron, lead, copper, silver, &c., because they are more readily obtained for the purpose of experiment. In the following table the first of a column is more electro-positive, and each one is positive to the one below it, and negative to the one above it.

The authority for each series, and the liquid in which the experiments were performed, are given at the head of each column. The yellow sulphuret, in column 10, was made by fusing equal weights of sulphur and caustic potassa, dissolving in water, and then diluting 1 vol. of the strong solution with 7 vols. water. The colorless, 11, was made by saturating a solution of potassa by sulphuretted hydrogen.

1. FECHNER.	2. DAVY.	3. PFAFF.	4. FARADAY.	5. MARIANINI.	6. FARADAY.
In Water.	Dilute Acid.	Dilute Acid.	1 Sulphuric, 1 Water.	Very dilut. Sulphuric.	Strong Muriatic.
Zinc	Zinc	Zinc	Zinc	Zinc	Zinc
Lead	Cadmium	Cadmium	Cadmium		Cadmium
Tin	Tin	Lead	Tin	Lead	Tin
Iron	Iron	Iron	Lead	Tin	Lead
Antimony	Bismuth	Bismuth	Iron	Iron	Iron
Bismuth	Antimony	Antimony	Nickel	Copper	Copper
Copper	Lead	Copper	Bismuth	Bismuth	Bismuth
Silver	Copper	Silver	Antimony	Nickel	Nickel
Gold	Silver	Gold	Copper	Antimony	Silver
	Palladium	Tellurium	Silver	Silver	Antimony
	Gold	Platinum		Mercury	
	Platinum	Palladium		Platinum	
	Rhodium			Gold	
7. FARADAY.	8. FARADAY.	9. FARADAY.	10. FARADAY.	11. FARADAY.	12. FECHNER.
1 Nitric, 7 Water.	Strong Nitric.	Solution Potassa.	Yellow Sulphuret.	Colorless Sulphuret.	Solution Com. Salt.
Zinc	Cadmium	Zinc	Zinc	Cadmium	Zinc
Cadmium	Zinc	Tin	Copper	Zinc	
Lead	Lead	Cadmium	Cadmium	Copper	Lead
Tin	Tin	Antimony	Tin	Tin	Tin
Iron	Iron	Lead	Silver	Antimony	Iron
Nickel	Bismuth	Bismuth	Lead	Silver	Antimony
Bismuth	Copper	Iron	Antimony	Lead	Bismuth
Antimony	Antimony	Copper	Bismuth	Bismuth	Copper
Copper	Silver	Nickel	Nickel	Nickel	Silver
Silver	Nickel	Silver	Iron	Iron	Gold
	Platinum		Platinum		Platinum

It will be observed that there is a general agreement of the different series, and the differences may be partly attributed to different degrees of purity in the metals employed, partly to a chemical action, according to the nature of the liquid and a resultant compound it may form, and partly to limited investigation.

There are other reasons, however, which have determined the electro-chemical series, as it is generally adopted, such as the similarity in composition and properties of the corresponding compounds of the different elements. In the present state of our knowledge it is impossible to present a correct arrange-

ment of the elements, either according to their pure chemical, or their electric relations. Berzelius divides them into two classes, according to their relations with oxygen, the most electro-negative element; into electro-positive bodies, which certainly form an electro-positive compound with oxygen, and electro-negative bodies, which either form no electro-positive compound with oxygen, or one which may be regarded as well negative as positive. This division which follows, is chiefly based on the electric relations of oxidized compounds, and is regarded by him as only approximately correct.

ELECTRO-CHEMISTRY.

— E.	Oxygen,	Gold,
	Sulphur,	Osmium,
	Selenium,	Iridium,
	Nitrogen,	Platinum,
	Fluorine,	Rhodium,
	Chlorine,	Palladium,
	Bromine,	Mercury,
	Iodine,	Silver,
	Phosphorus,	Copper,
	Arsenic,	Bismuth,
	Chromium,	Tin,
	Vanadium,	Lead,
	Molybdenum,	Cadmium,
	Tungsten,	Cobalt,
	Boron,	Nickel,
	Carbon,	Iron,
	Antimony,	Zinc,
	Tellurium,	Manganese,
	Columbium,	Uranium,
	Titanium,	Cerium,
	Silicium,	Thorium,
	Hydrogen.	Zirconium,
		Aluminum,
		Didymium,
		Lanthanum,
		Yttrium,
		Glucium,
		Magnesium,
		Calcium,
		Strontium,
		Barium,
		Lithium,
		Sodium,
	+ E.	Potassium.

1. O, S, Se, Te

2. F, Cl, Br, I

3. N, P, As, Sb

4. C, B, Si

5. M, V, Cr

6. Ti, Ta, Nb, Pp, W

7. H, Os, I, Pt, R, Pd, Au

Ag, Hg, Cu, Pb, Bi 8.

L, Na, K 14.

Mg, Ca, Sr, Ba 13.

D, La, Y, G 12.

Ce, Zr, Th, Al 11.

Ni, Co, Fe, Mn, U 10.

Sn, Cd, Zn 9.

Electrolysis. When successive discharges of electricity of high tension, as from a Leyden jar, are passed through some compound gases, they are resolved into their elements or simpler compounds. Thus, the carbo-hydrogens are resolved into carbon and hydrogen; sulphuretted and phosphuretted hydrogen, chlorohydric, iodo-hydric and ammoniacal gases, are respectively resolved into sulphur, phosphorus, chlorine, iodine and nitrogen on the one side, and hydrogen on the other. Carbonic acid is partly resolved into oxygen and carbonic oxide. A few solids are similarly decomposed, as oxide of mercury, chloride of silver, and even caustic potassa.

When a constant current of low tension from a galvanic battery is passed through a compound liquid, which completes the circuit, then, if the liquid be a good conductor, it remains unaltered; if it be a non-conductor, it also remains unaltered, unless the current have a high tension; but if the liquid be an

imperfect conductor, it is decomposed and resolved into its elements, or into simpler compounds. Gases being non-conductors, are not decomposed; solids mostly remain unchanged, because their particles are destitute of freedom of motion.

There is a remarkable analogy between sets of 3 or 4 elements, by which we may arrange them into groups, and these again into a series more or less electrical. The following is similar to the arrangement offered by Gmelin, and for the sake of perspicuity as well as a more rapid oversight, the elements are only represented by their symbols.

Gmelin places oxygen over the left hand column, hydrogen over the right and nitrogen in the middle, between them, because "they are isolated, and have no analogous elements." To show, however, how defective such an electro-chemical arrangement is, silicon, Si, in group 4, is in some respects allied to aluminum, Al, in 11; for alumina sometimes seems to occupy the place of silica in minerals; Cr, in 5, is allied to Fe, in 10, and Al, in 11; for the sesquioxides of chrome and iron and alumina are isomorphous, and replace each other; antimony, Sb, in 3, is closely allied to bismuth, Bi, in 8, and yet it appears to be more nearly related to arsenic. But the chemical behavior of the different series of compounds formed by the elements, conjoined with electrical indications, has been made the basis of all the arrangements which are now adopted by chemists.

The wires or conductors, from the two poles of the battery, which terminate in the liquid without contact with each other, are termed by Faraday the *Electrodes*; that conveying the + or positive current being the *anode*, *zincode* or *oxode*; that conveying the — or negative current, the *kathode*, *platinode*, *chlorode* or *hydrogode*. Such decompositions are termed *electrolysis*, and the decomposable liquid an *electrolyte*. The electro-negative body appearing at the anode, is termed an *anion*; the electro-positive body issuing at the kathode, is a *kation*; and the two together are termed *ions*. The vessel in which electrolysis is performed, is termed the *decomposing cell*.

The phenomena of decomposition are differ-

ent, according to the nature of the substances decomposed, appearing as gas, as oxygen and hydrogen from water; in solid form, as silver from cyanide of silver; dissolved in the liquid, as potassa and sulphuric acid from sulphate of potassa; combined with the electrode, as fluorine from fluoride; or combining with parts of the liquid, to form secondary products.

Only such binary compounds are electrolytes, as consist of one equivalent of each element; as water, the hydracids and simple metallic oxides; while sulphuric, SO_3 , sulphurous, SO_2 , and boracic acid, BO_3 , chlorides of phosphorus, PCl_3 , of sulphur, S_2Cl_2 , of carbon, C_4Cl_6 , of antimony, SbCl_5 , &c., although liquid, are not decomposable. A few are excepted to this rule. It is probable that all the elements are ions. The anions are oxygen, chlorine, bromine, iodine, fluorine, the elementoid cyanogen, and probably sulphur and selenium; the kations are hydrogen, the alkaline metals, ammonium, manganese, antimony, bismuth, zinc, cadmium, tin, lead, iron, cobalt, nickel, copper, mercury, silver, gold, platinum. In ternary compounds, salts, the acids are anions or electro-negative, and the bases kations or electro-positive.

The quantity of electricity entering an electrolyte, is in direct proportion to the ions evolved, so that the amount of the last may be employed to determine the quantity of electricity. By inserting an inverted and graduated tube filled with acidulated water in the circuit, the measured volume of oxyhydrogen gas, generated in a given time, may serve to determine the amount of electricity. Such an apparatus is termed a *voltameter*.

The same quantity of electricity will decompose equivalent quantities of bodies. If fused chloride of tin be decomposed by a battery, in the circuit of which the voltameter is inserted, for every 9 pts. (= 1 eq.) of water decomposed in the latter, 58.53 pts. of melted tin were produced (1 eq. tin = 58.9). By decomposing chloride, iodide and oxide of lead, the quantities of lead were somewhat less than the equivalent of lead; but by employing lead as the positive electrode, the quantities indicated for 9 pts. water decomposed, were 101.5 and 103.5 (1 eq. lead = 103.8). (*Faraday*.) By passing a current through the solutions of two different metals, they are precipitated in equivalent quantities, or nearly 4 times as much silver as copper. (*Matteucci*.)

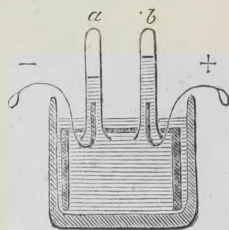
The quantity of a body decomposed is equivalent to the quantity of the body which, by its chemical action, produces the galvanic current; or rather it approaches so closely to this proportion, that the variation may be attributed to imperfection of the apparatus. For every 9 pts. (= 1 eq.) water decomposed in the voltameter, a little more than 32.2 pts. (1 eq.) zinc are dissolved in each cell of the battery. (*Faraday*.) In Daniell's constant battery with amalgamated zinc, 33.6 pts. zinc are dissolved in each cell, for every 9 pts. water decomposed. (*Jacobi*.)

Some decompositions are effected with the feeblest currents, as iodide of potassium; while acidulated water apparently requires a

current of much higher tension for decomposition. According to Jacobi, feeble currents pass through water without effecting electrolysis. Water will not conduct the electric current without decomposition. (*Grove*.) A single pair decomposing iodide of potassium, does not decompose water, unless nitric be added to the sulphuric acid of the pair, whereby the tension is increased. (*Faraday*.) A pair of zinc and copper of a square-meter surface, with sulphuric acid alone, without nitric acid, decomposes nitrate of silver, so that the decomposition depends wholly on the quantity of electricity. (*Matteucci*.)

The chemical nature of an electrolyte influences its decomposition. Pure water is decomposed with much more difficulty than when certain acids, salts, or the fixed alkalies, are dissolved in it. With a battery of 40 pair, water acidulated with sulphuric acid gives 15 times as much hydroxygen as pure water. (*Faraday*.) A zinc-copper pair excited by water, with copper electrodes, gives a stronger current through dilute sulphuric acid, than one excited by dilute sulphuric acid through water. (*Buff*.) The electrolyte is more rapidly decomposed when hot than when cold; and by heating the kathode, the current is increased, which may perhaps be due to the freer escape of gas. Water continues to decompose even under a pressure of 150 atmospheres. The nature of the electrode influences the facility of decomposition, by adding its own attraction for the ion, which it develops from the electrolyte.

In experimenting on the decomposition of bodies, various forms of apparatus may be employed, according to the nature of the electrolyte and the ions. The former is usually contained in a vessel which will not act on it chemically; and if the latter be gaseous, the gas or gases may be collected in inverted vessels filled with liquid. Thus the adjoining cut represents an apparatus for collecting separately the gaseous products from the decomposition of water, and consists of two test tubes, *a* and *b*, fastened in a wooden shelf, which will sink and be steadied by a weight of lead. The tubes are filled with acidulated water, and being closed by the fingers, are inverted in a tumbler or other



convenient vessel, filled with the same liquid. Platinum electrodes from the poles of the battery terminate, each in one of the tubes. By this arrangement the two gases, oxygen and hydrogen, are collected separately, the former or anion being evolved from the anode, + or zinc pole, and the hydrogen or kation, from the kathode or - pole. Their relative quantity may be measured by the eye, or by having the tubes graduated. For the mixed gases or for a single gas, one tube is employed, in which one or both electrodes terminate without contact. Instead of the above arrangement, a

single decomposing cell may be employed, divided by a porous diaphragm, on either side of which an electrode terminates, and allows of a separation of the ions. For the decomposition of a salt, as sulphate of soda, three cups or watch-glasses, *a*, *b* and *c*, may be employed, the three being connected by moistened asbestos fibres; *b* containing the solution of salt, *a* a solution of turmeric, and *c* a solution of litmus; the kathode terminates in *a*, and the anode in *c*. By passing a current through, the browning of turmeric and reddening of litmus show the passage of the alkali to the kathode, *a*, and of the acid to the anode, *c*. For the precipitation of metals, see **ELECTROTYPE**.

The following examples may illustrate variations in the decompositions. Dilute acids in general facilitate the decomposition of water, without being themselves decomposed. Dilute sulphurous acid gives oxygen and sulphuric acid at the + pole, and hydrogen and sulphur at the kathode. Strong nitric acid gives oxygen at the + pole, and nitric oxide at the — pole. Strong muriatic gives chlorine at the +, and hydrogen at the — pole; but if the anode consist of iron, copper, silver, &c., a chloride is formed and remains in solution, except chloride of silver; iodo, bromo and cyanohydric acids, when strong, yield the halogen body at the +, and hydrogen at the — pole. In all these hydracids, the more dilute the acid or the stronger the current, the more oxygen and the less of the halogen body is developed.

Slightly moistened potassa and soda yield to a strong current oxygen at the anode, and

hydrogen with potassium or sodium, at the kathode; the metal hangs in drops on the platinum wire, and burns. Hydrates of baryta, strontia, lime and magnesia, are not decomposed, unless the kathode dip in mercury, when an amalgam of their metal is produced.

The fused metallic chlorides and iodides give metal at the kathode, and the halogen at the anode. Solutions of alkaline chlorides, with the kathode dipping in mercury, give an amalgam at this pole and chlorine at the anode. A solution of protochloride of iron gives black magnetic iron at the kathode. Solutions of fluorides give at the anode fluorine, which unites with it, even if platinum be used. Sal-ammoniac solution yields chlorine at the anode, and hydrogen and ammonia at the kathode. If mercury be used at the kathode, it swells up, forming the ammoniacal amalgam.

The alkaline sulphates, phosphates and borates in solution, generally yield alkali and hydrogen at the kathode, acid and oxygen at the anode. Salts of the metals proper are usually resolved into oxygen and acid at the anode, and reduced metal at the kathode; but if the current be very strong, hydrogen also appears at the kathode. If the electrodes consist of the same metal as the base of the electrolyte, the anode is dissolved by the oxygen and acid there evolved, and an equivalent quantity deposited on the kathode. Salts of manganese, lead and silver, yield hyperoxides at the anode. In these cases there is little or no evolution of gas. See farther, under **ELECTROTYPE**.

ELECTRIC CALAMINE. *Min. Syn.* Siliceous Oxide of Zinc. *Ger.* Galmei (in part). Zinkglas. Cryst. Right Rhombic, consisting of the vertical and horizontal prisms, main end-plane and second side-plane, cleaving perfectly parallel to the vertical prism. Generally imperfectly crystallized, fibrous; also massive and granular. $H. = 4.5 - 5$. $G. 3.38 - 3.43$. Color white, variously tinted; lustre usually vitreous; transparent, translucent; brittle, with uneven fracture. Becomes electric by friction or heat.

Chem. Relat. Yields water in a closed tube, fuses with difficulty on the edges, gives the zinc coating to charcoal alone or with soda, becomes green with cobalt-solution and on the fused edges blue. Easily soluble in acids, gelatinizing, and partly in caustic potassa. Form. $2(3 ZnO, SiO_3) + 3 HO$.

Local. It occurs in Siberia; Hungary; at Bleiberg, Carinthia; Altenberg; near Aix la Chapelle; Mendip Hills, Wanlockhead, Scotland. In the U. S., Hamburg, near Franklin Furnace, N. J.; Perkiomen, Penn.; Wythe Co., Virginia; Jefferson Co., Missouri; at the lead mines of Iowa, Wisconsin, and Illinois. Together with Calamine it yields the greater part of the zinc of commerce. See CALAMINE and WILLEMITE.

ELECTROTYPE. *Syn.* Galvanotype, Electro-metallurgy, Galvanoplastic. An art first made known by Jacobi and Spencer. Through the agency of voltaic **ELECTRICITY** metals are precipitated from their solutions in thin layers, and in this manner can be produced facsimiles of medallions, indented or raised surfaces, and moulds generally.

The piles in which this power is generated are of several forms, those in general use being known, respectively, as Grove's, Smee's, Bunsen's, and Daniell's batteries.

Grove's Battery. This apparatus is one of the greatest intensity, and hence is not so well adapted for galvanoplastic. Although constructed of small dimensions, with four or five elements, it may develop the most energetic effects, and produce every decomposition, and redden a platinum wire. Thus the dimensions of each pair may be three centimetres only, in taking for diaphragms bowls of earthen pipes closed at their base. In the interior, the amalgamated zinc is plunged into the saline solution, and on the exterior platinum is immersed in nitric acid. The zinc is negative, and the platinum positive.

Smee's Battery. This apparatus (fig. 62) is very simple. A plate of platinized silver is surrounded by a plate of zinc; the zinc is the posi-

Fig. 62. SMEE'S BATTERY.

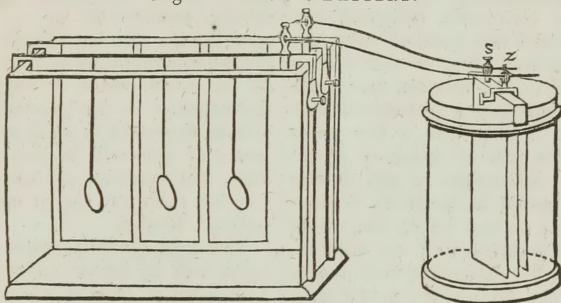
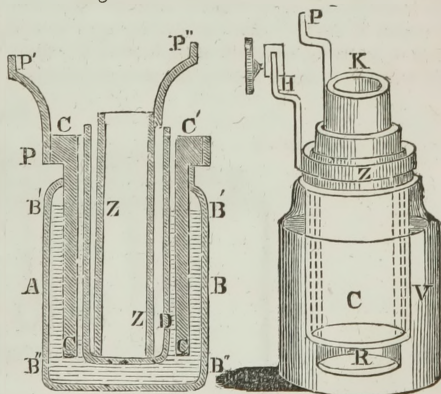


Fig. 63. BUNSEN'S BATTERY.



tive, and the platinized plate the negative pole. The only liquid requisite for exciting this battery consists of 1 pt. sulphuric acid and 7 pts. water. Its power may be increased by adding more acid, which ought not, however, to exceed one-fourth of the whole liquid. The addition of a few drops of nitric acid augments the intensity, but as it might attack the silver, it is better to employ it only when the negative plate consists wholly of platinum.

The silver plate is platinized by roughening the surface with a little strong nitric acid, and, after washing, putting it in a vessel of water, acidulated with sulphuric acid, added to which are a few drops of chloride of platinum. A porous vessel, containing dilute sulphuric acid, is plunged into the liquid, and receives in its turn a plate of zinc. Communication being established between the two metals, the platinum is precipitated upon the silver surface as a blackish metallic powder.

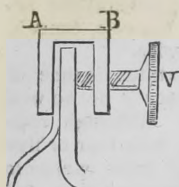
Bunsen's Battery. It is founded upon the same principles as Grove's battery, but with a cylinder of porous coal instead of platinum. Fig. 63 represents this convenient and economical apparatus.

A B is a glass vessel, filled up to B' B' with

commercial nitric acid; C and C' hollow charcoal cylinders, dipping into the acid as far as B'' B'', and resting on the edge of the glass by a flange. A ring of zinc, or better of copper, P, is adjusted by gentle friction upon the charcoal cylinder, and terminates in an appendage, P', for establishing communication either with the zinc of another element, or with the soluble electrode of a precipitating trough, if only a

single cell is employed. DD are diaphragms of porous earthenware, containing dilute sulphuric acid, and the hollow cylinder of amalgamated zinc, ZZ, which also terminates in an appendage, P', for communicating the zinc with the charcoal element of another pair, or for connecting with the conductor of the model to be covered.

Fig. 64.



The different connections are established by a clamp, A B, and screw, V, as shown separately in fig. 64, or in place at H, in fig. 63.

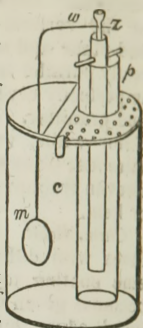
It is necessary to carefully brighten with sandpaper the appendages of the two poles and the copper ribbons, which are preferable to copper wire for establishing communication. The interior of the clamps should also be cleansed, and the screws so adjusted as to ensure a perfect contact of all the parts. Fig. 63 represents the whole apparatus.

The battery is charged, by half filling the glass vessel with commercial nitric acid, diluted with its volume of water, and the diaphragm with water slightly acidulated by sulphuric acid.

In intensity, this apparatus, says the inventor, is scarcely inferior to that of Grove's, a single pair being sufficient. The coal cylinder is made by intimately mingling one part of caking coal and two parts of coke, the proportions varying according to the caking property; some add to the mixture two parts of rye flour. The mixture is introduced into a cylindrical mould of sheet iron, in the centre of which is placed a core of wood or pasteboard, to facilitate the escape of gas during calcination. The mould is closed by a movable cover well fitted on and luted; the whole heated gradually to redness, and the calcination continued until the disengagement of gas ceases. The cylinder may be finished with a file or saw, or on a lathe. Before proceeding to this last operation, in order to increase the cohesiveness of the cylinders, it is necessary to soak them in a strong solution of molasses, dry them, and subject them to a very intense calcination.

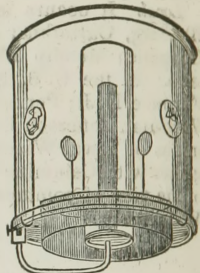
But the apparatus most generally used in electrotype, especially for the more costly metallic solutions, is shown by fig. 65.

Fig. 65.



To put this in action pour in the copper solution, fill the tube with the acid-water, and place it as shown in the figure. Last of all, put in the bent wire, having the zinc at one end and the mould at the other.

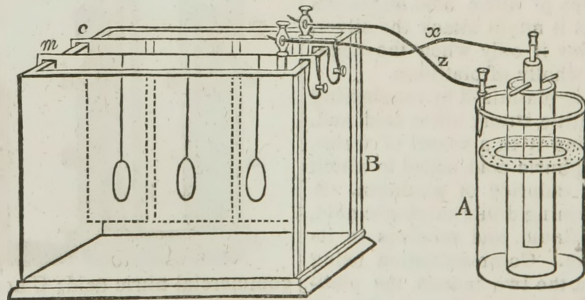
Fig. 66.



Another form of this apparatus is shown by fig. 66. The zinc is connected by a wire and binding screw, with a metal rim, and on the latter can be hung several moulds. Jacobi's improvement upon the above form enables the taking copies of the same medal simultaneously, to an indefinite extent, merely by increasing the number of cells, and without any further consumption of material in the battery, as for every ounce of copper released from the solution in the generating cell, an ounce will be deposited in each mould, and about an ounce of zinc will be consumed in effecting this; this amount of zinc will be required whether there are one or twenty moulds in the series. Walker.

The arrangement, called the battery apparatus, will be better understood from fig. 67. A is a cell of Daniell's battery, B the decomposition cell, filled with the dilute acid solution of sulphate of copper, c the sheet of copper to furnish a supply, m the moulds to receive the deposit. To charge this, pour in the several solutions: hang a piece of copper on the brass

Fig. 67.



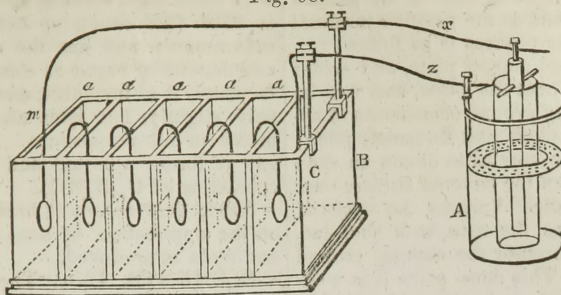
rod, c; connect this rod with the copper of the generating cell by the wire, z; and the other rod m, with the zinc, by the wire, x; then, and not till then, hang the moulds on the rod, m.

By the galvanic action, the copper from the solution is transferred to the mould; and the copper sheet is dissolved, being converted

with the sulphuric acid into sulphate of copper; thus keeping up the strength of the solution. The time is somewhat longer by this method: two days will produce a medal of very good substance, firm and pliable.

Fig. 68 is an engraving of a Daniell's battery, connected with a series of six cells, in

Fig. 68.



each of which is a mould. A, the battery; B, the trough; z, wire connecting copper-plate, C, with the negative plate of the battery; x, wire connecting mould, m, with the zinc of battery; a a a a a, five bent wires, each having a mould at one end and a piece of copper at the other. A little management is requisite in charging this, in order to preserve the bright surface of the medals produced. Charge the battery; connect the copper plate, C, with the battery; place a wire with its extreme ends dipping in the extreme cells of the trough; then, having previously connected the zinc and mould with the wire, x, place the zinc in the porous cell and the mould in its place at m. The latter, in about two minutes, will be covered with copper; after which there is no fear of chemical action. Then remove the end of the copper wire from cell containing m, and place it in the next cell;—complete the circuit with the bent wire, a, having a mould at one end, and a sheet of copper at the other; after waiting two minutes for a deposit of copper, remove the end of the wire one cell further forward; and so continue till the six moulds are placed in.

The copies of objects are taken from moulds which are placed at the negative pole of the battery. These moulds are made of fusible and type metals, wax, stearin, plaster of Paris, and a composition of wax, stearin, and black lead, or wax and flake white. Those from non-conducting material are metallized or rendered conductors by the application of dry plumbago, which must be rubbed briskly over their surface.

If the fusible metal mould is placed in the copper solution before the battery is in action, a dark precipitate will be chemically formed upon its face, and to guard against this, and to ensure the instantaneous deposit of a metallic film, free of oxide, the arrangements should be all made, and the circuit completed, before the immersion of the mould. Upon the plumbagoed surfaces the deposition of copper is more gradual, and as these moulds become wetted, and lose their metallic covering, they should be recoated previous to being used again.

The necessary manipulations are detailed in two small manuals upon the subject by Walker.

Busts, statues, vases, &c., are, by proper arrangements, as readily copied as medals, and though copper is the metal generally alluded to, yet, with proper care, all of the metals may be obtained from their several solutions.

As experiment has shown that cyanogen, nascent at the positive plate, in a decomposition cell, will combine with silver, and also with gold, so gilding and plating can be effected, as copper deposits are obtained, by the use of a generating cell to furnish the electricity, and a decomposition cell to contain the cyanide solution. A longer time is, however, required. In all cases where adhesion is desired, the deposition of the metal should be assisted by heat.

The gold bath is prepared by dissolving a quarter of an ounce of oxide of gold, in a solution of two ounces of cyanide of potassium, in a pint of warm pure water.

Silver Bath. Substitute the oxide of silver for that of gold, and prepare as directed for the gold bath.

Platina Bath. A double chloride of ammonium and platinum, to which some drops of liquid ammonia are added, at a moderate temperature. Böttger obtained from this solution whilst warm, a brilliant adhesive deposit, which resisted the action of acids.

Nickel Bath. Either the nitrate or the ammoniacal sulphate of the protoxide of nickel can be employed.

Tin Bath. This metal, as also lead, are deposited with difficulty. Its solution in aqua regia, acidulated with nitric acid, is most applicable. Sometimes it is deposited from a solution of its oxide in potassa, or of the metal itself in super tartrate of potassa.

Copper Bath. The sulphate is the salt most used, and some acidulate the solution with nitric acid, but this addition is contrary to the advice of Jacobi and Spencer. The sulphate of copper solution should be kept always saturated with large crystals.

The application of the electrotype has been extended to the plating of objects of ornament, for use in the arts, and for domestic purposes. Cast iron can be silvered with a solution of chloride of silver in cyanide of potassium (*Ch. Gaz.* i. 583), and even lace can be metallized by covering it with plumbago, stretching it over a frame of copper wire, and subjecting it to voltaic action between two plates of copper positively electrified.

The objection to this method of silvering copper vessels for domestic purposes, is, says Warrington, the porosity of the plated surface allowing the permeation of corrosive liquids. Hence they are readily acted upon by dilute acids.

Electro-etching, by which the tracing upon a prepared ground, or even Daguerreotype pic-

tures, are rendered bold enough to be printed from, is accomplished at the positive terminal of the battery. The process is as follows:

Take a burnished copper plate, and solder to it a stout wire; heat the plate, and rub its surface with etching ground (consisting of asphalt, wax, black pitch, and Burgundy pitch) wrapped in silk; be careful to obtain an even coating; then smoke the covered surface over the flame of a candle. Varnish the back of the plate, as well as the wire, with shell-lac. Trace the design through the etching ground with a fine point. This done, place it in a decomposition cell, and connect it with the copper of a Daniell's battery, placing opposite to it a plate of somewhat similar size; after the lapse of ten minutes remove it, and "stop out" the fine parts with Brunswick black; return it to the decomposition cell for a second ten minutes; and again stop out the half tints; again submit it to action for ten minutes, and the operation is complete. Remove the etching ground by means of heat, and a perfect engraving will be found on the plate.

The engraving or etching of the Daguerreotype plates is effected in a different manner, and by more careful and difficult manipulation. In Walker's manuals, before referred to, will be found all the necessary instruction.

ELEMI RESIN. *Chem.* A product of the *Amyris elimifera* of the West Indies, or *Ceylanica* of the East Indies. Its formula is $C_{40}H_{33}O$ (Rose), or $C_{20}H_{16}O$ (Hess). Spec. grav. 1.08.

Of the two resins which it contains, one is crystallizable and soluble in cold alcohol, and the other amorphous and less carbonated, but more oxygenated than the former. This discrepancy is attributed by Rose to the assumption of the elements of water during the slow crystallization of the first resin; and the formation of the amorphous resin, and the mixture of its hydrate thus accounts for differing analytic results. Rose's formula corresponds with that given by Laurent to ANIME. The silver and lead salts produce no precipitates in the alcoholic solution, but ammonia transforms it into a jelly.

By distillation with water, it yields a colorless limpid oil, which polarizes to the left, and

is of spec. grav. 0.849 at 52°. Its boiling point is 330° (Stenhouse), or 345° (Dewille). It is inflammable, and has the same composition and density of vapor as essence of terpentine. In water, it is insoluble, and, in dilute alcohol, only slightly, but with alcohol and ether it mixes in all proportions. With chlorhydric gas it forms a liquid and a solid camphor, consisting of $C_{10}H_8HCl$.

Nitric acid colors it brownish yellow, and on the application of heat, explosion occurs, and resin is produced.

ELEMENTS. *Chem.* The term Elementary, when applied to a body, designates it as simple and undecomposed. An element, therefore, is a substance, which has resisted attempts to decompose it into constituent parts. There are 63 accredited simple bodies, and of one or more of this number, all the known compounds in nature are composed.

The best classification of the elements is that founded on their electro-chemical relations. A convenient arrangement divides them into two classes, the metalloids and metals. The former include oxygen, sulphur, selenium, hydrogen, nitrogen, and phosphorus; carbon, boron, and silicon; fluorine, chlorine, bromine, and iodine. It will be observed, that they are subdivided according to their mutual relations. Those of the last subdivision are termed halogen bodies. The metals may be subdivided into the bases of the earthy bodies, and the metals proper; the former of which comprise potassium, sodium, and lithium, forming alkalies; barium, strontium, calcium, and magnesium, forming alkaline earths, and alumina, glucina, zirconia, yttria, and thorina, forming earths.

The metals proper comprise those whose lower oxides are strong bases, as cerium, lanthanum, manganese, iron, zinc, cobalt, nickel, which more easily decompose water than uranium, lead, and copper; those whose oxides are less strong bases, and are decomposed by heat, as mercury, silver, gold, platinum, palladium, rhodium, iridium, and osmium; those whose higher oxides are acids, as tin, titanium, tungsten, columbium, molybdenum, vanadium, chromium, bismuth, antimony, arsenic, and tellurium. Below is an alphabetical table.

Names.	Sym-bols.	EQUIVALENTS.		Specific Gravity. Water=1.	Spec.Grav. of Gas. Air = 1000.	Specific Heat. Water=1.	Fusing Points. Fahr.	Atomic Number.
		O = 100.	H = 1.					
Aluminium	Al	171.17	13.72	?	.....	?	?	?
Antimony (Stibium) ..	Sb	1612.9	129.2	6.7	.....	.0508	800°	.0519
Arsenic	As	940.08	75.3	5.7	10362	.0814	356°	.0757
Barium	Ba	856.88	68.66	?	.....	?	?	137.6
Bismuth	Bi	2660.7	213.	9.8	.....	.0308	500°	.046
Boron	B	136.2	10.8	?	.....	?	?	.038
Bromine	Br	978.31	78.39	2.97	5540	.1350	liquid	70.
Cadmium	Cd	696.77	55.8	8.635	.....	.10567	442°	.1547
Calcium	Ca	251.94	20.15	?	.....	?	?	?
Carbon	C	75.12	6.	3.5	.....	.2000	?	.5833
Cerium	Ce	574.70?	46.05?	?	.....	?	?	?
Chlorine	Cl	442.65	35.4	1.333	2454.3	.....	.....	.0376
								69.3

ELIQUATION.

ELIQUATION.

Names.	Sym- bols.	EQUIVALENTS.		Specific Gravity. Water=1.	Spec.Grav. of Gas. Air=1000.	Specific Heat. Water=1.	Fusing Points. Fahr.	Atomic Number.
		O = 100.	H = 1.					
Chromium.....	Cr	351.82	28.16	5.9	.....	?	?	.21
Cobalt.....	Co	368.99	29.60	8.538	.....	.1070	?	.2885
Columbium.....	Ta	2307.43	184.90	?	.....	?	?	?
Tantalum.....								
Copper (Cuprum) ..	Cu	395.70	31.71	8.920	.....	.0951	1996°	.2814
Didymium.....	Di	?	?	?	.....	?	?	?
Erbium.....	E	?	?	?	.....	?	?	?
Fluorine.....	F	233.80	18.74	?	?	?	?	?
Glucinum.....	G	58.08	4.	?	.....	?	?	?
Gold (Aurum).....	Au	2486.02	199.	19.25	.....	.0324	2016°	.0961
Hydrogen.....	H	12.47	1.00	?	69.3	3.2936	.....	69.3
Ilmenium.....	Il	?	?	?	.....	?	?	?
Iodine.....	I	1579.50	126.	4.948	8716	.0541	225°	.039
Iridium.....	Ir	1233.50	98.7	?	.....	.0368	?	69.1
Iron (Ferrum).....	Fe	339.21	27.18	7.8	.....	.1138	2850°	.2883
Lanthanum.....	La	?	?	?	.....	?	?	?
Lead (Plumbum)....	Pb	1294.50	103.7	11.35	.....	.0314	617°	.1090
Lithium.....	L	80.33	6.4	?	.....	?	?	?
Magnesium.....	Mg	158.35	12.69	?	.....	?	?	?
Manganese.....	Mn	345.89	27.6	8.?	.....	.1441	?	?
Mercury.....	Hg	1265.82	101.4	13.559	6976	.0333	—39°	.1337
(Hydrargyrum)....								68.8
Molybdenum.....	Mo	598.52	48.	8.6	.....	.0722	?	.1792
Nickel.....	Ni	369.68	29.62	8.637	.....	.1086	?	.2918
Niobium.....	Nb	?	?	?	.....	?	?	?
Nitrogen.....	N	177.04	14.	9.76	970.6	.2754	.....	69.3
Norium.....	No	?	?	?	.....	?	?	?
Osmium.....	Os	1244.49	99.7	10.	.....	?	?	.1000
Oxygen.....	O	100.00	8.	.....	1109.3	.2361	.....	138.6
Palladium.....	Pd	665.90	53.3	11.4	.....	.0593	?	.2139
Pelopium.....	Pe	?	?	?	.....	?	?	?
Phosphorus.....	P	392.28	31.4	1.77	4420	.1887	115°	.0557
Platinum.....	Pt	1233.50	98.8	21.5	.....	.0324	?	140.8
Potassium (Kalium) .	K	489.92	39.2	0.865	.....	?	136°	.2176
Rhodium.....	R	651.39	52.20	11.2	.....	?	?	.022
Ruthenium.....	Ru	?	?	8.6	.....	?	?	.2146
Selenium.....	Se	494.58	40.	4.31	.....	.0837	215°	?
Silicon.....	Si	277.31	22.22	?	.....	?	?	.1077
Silver (Argentum) ..	Ag	1351.61	108.30	10.474	.....	.0570	1873°	?
Sodium (Natrium) ..	Na	290.90	23.3	0.972	.....	?	190°	.096
Strontium.....	Sr	547.29	43.85	?	.....	?	?	.0416
Sulphur.....	S	201.17	16.12	1.98	6900	.2026	226°	?
Tellurium.....	Te	801.76	64.	6.25	.....	.0515	700°?	.1228
Thorium.....	Th	744.90	59.88	?	.....	?	?	428.0
Tin (Stannum).....	Sn	735.29	59.	7.29	.....	.0562	446°	.0978
Titanium.....	Ti	303.66	24.3	5.28	.....	?	?	?
Tungsten (Wolfram) W	W	1183.00	95.	17.4	.....	.0364	.....	.1236
Terbium.....	T	?	?	?	.....	?	?	.2173
Uranium.....	U	750.	60.	?	.....	?	?	.1831
Vanadium.....	V	856.89	68.6	?	.....	?	?	?
Yttrium.....	Y	402.51	32.25	?	.....	?	?	?
Zinc.....	Zn	403.23	32.3	6.915	.....	.0955	773°	.2145
Zirconium.....	Zr	420.20	33.67	?	.....	?	?	?

Where two numbers are given for the same element in the column of atomic numbers, the fractional number is obtained by dividing the specific gravity compared with water by the equivalent, and the larger number from its spec. grav., in the gaseous form, compared with air.

ELIQUATION. *Met. Syn. Liquefaction.* The

term originates from *liqueo*, to dissolve or to melt, and is applicable to the separation by heat of a more fusible metal from its less fusible alloy. For example, the slow and gradual cooling of a mixture of several metals of different densities and fusing points, develops each in a separate stratum. Liquefaction is the process used for the purification of tin con-

taining a little copper and lead; and also in the treatment of argentiferous copper ores. See the metallurgic treatment of **ANTIMONY**, **BISMUTH**, **COPPER**.

ELLAGIC ACID. See **TANNIN** and **GALLS**.
ELUTRIATION. *Chem. Tech.* Syn. Washing over. From *elutrio*, I cleanse. In metallurgy it applies to the cleansing and washing of pulverized ores with large quantities of water, so as to suspend their finer portions, and thus separate them from the heavier or metallic particles merely by drawing off the water before complete subsidence ensues. The process is entirely mechanical, and in chemical and other arts is used for freeing precipitates and powders of their grosser parts. Whiting, for example, is made from crushed chalk by elutriation,—by stirring a given quantity in water and drawing it off into another vessel as soon as the weightier particles have settled. A careful management secures the separation of all the valuable portion without unnecessary loss.

EMBRITHITE. See **BOULANGERITE**.

EMERALD. See **BERYL**.

EMERALD COPPER. See **DIOPTASE**.

EMERY. See **CORUNDUM**.

EMETIN. See **IPECACUANHA**.

EMMONSITE. See **STRONTIANITE**.

EMPYREUMA. *Chem.* From *εμπυρεμα*, to inflame. It is the burned odor peculiar to the products of **DRY DISTILLATION**. More or less modified by attendant circumstances, it is a general accompaniment of the imperfect combustion of organic substances.

EMPYREUMATIC OILS. So called from their diffusive empyreuma. They form that portion of the products of the **DRY DISTILLATION** of wood and organic matter which has an oleaginous aspect. Its volatile ingredients, consisting partially of ammonia, uncombined, and as subcarbonate and acetate, when separated by repeated distillations with water, leave a resinous residuum, which is capable of ready union with alkalis. The title of Empyreumatic is frequently applied to **DIPPEL'S ANIMAL OIL**.

EMULSIN. *Chem.* Syn. Synaptase, Amanadin. An animo-vegetable albuminous white substance, existing abundantly in the trees of the genus *Rosaceæ*, and constituting the mass of the cotyledon of sweet and bitter almonds. Its peculiar reaction upon the **AMYGDALIN** component results in the decomposition of both, and the formation of volatile oil of almonds.

Prep. Emulsin was first obtained by Wohler and Liebig, from an emulsion of sweet almond, the oil of which had been previously removed by ether. The transparent, syrupy liquid remaining, treated with alcohol, drops an abundant white precipitate, which, when dried, forms a horny, opaque mass, and decomposes with the evolution of much ammonia when boiled with barytic water or solution of caustic alkali. Under the name of *synaptase*, it was procured by Robiquet, from the *marc* of sweet almonds, after the expression of the oil by macerating it for two hours in twice its weight of water, and then pressing out the liquid portion. This, when filtered,

contains vegetable albumen, which is thrown down by acetic acid, and gum, which is precipitated by acetate of lead. The remaining liquid contains free acetic acid, acetate of lead, sugar, and synaptase; the lead is thrown down by sulphuretted hydrogen, and the synaptase by alcohol, while the free acid and sugar remain in solution. The precipitated synaptase is to be washed in alcohol, and dried in vacuo. This and emulsin are identical, but myrosin, with which, by some chemists, it is also classed, possesses distinct properties. The last exists in the seeds of black and white mustard, but can only be extracted from the latter, as the first contains some myronates; among them that of lime, upon which it reacts as soon as water is present, transforming it into volatile oil of mustard, whilst synaptase has the distinct power of determining the benzoic fermentation.

Prop. Synaptase is soluble in water, but insoluble in alcohol and ether. In a fresh solution iodine produces a deep rose color, (not observed. *Ortloff*.) Rennet precipitates it completely. At 140° it coagulates like albumen, unless mineral and vegetable acids be present, which distinguishes it from that substance. (*Ortloff*.) It is coagulated by acetic acid, and redissolves in an excess, and, by this property, resembles vegetable casein. It is evidently allied to these last substances, though, according to Dumas's analysis, it differs widely in composition from that of those two groups of bodies.

	<i>Emulsin.</i>	<i>Protein.</i>
Carbon.....	50.9	55.
Hydrogen.....	6.5	7.
Nitrogen.....	18.5	16.
Oxygen.....	24.1	22.

Notwithstanding this discrepancy, says Baudrimont, and independent of the before-noted properties, *amandin*, like all the protein groups, dissolves in chlorohydric acid, imparting to it a deep blue color; but, according to *Ortloff*, it dissolves in that acid, forming a colorless solution. If it belong to the protein-group, the protein exists in union with a more azotized matter. It may also be said, with some reason, that the animal albumen originating from vegetable albumen, is the latter de-azotized, or in combination with another containing less nitrogen.

Comp. The difficulty attending the analysis of amorphous organic bodies, and the impossibility of eliminating them free of foreign matter, has prevented an accurate estimation of the composition of emulsin. The following analyses are by Dr. R. D. Thomson and Richardson.

Carbon.....	49.025	48.555
Hydrogen.....	7.788	7.677
Oxygen.....	24.277	25.026
Nitrogen.....	18.910 T.	18.742 R.

But the analyses given by *Ortloff* differ widely from these, and it seems that he has succeeded in separating albumen from emulsin, whence both the difference in properties and composition determined by him. Dried at 212°, after deducting 17.55 pr. ct ash, he

found, as an average of 3 analyses, 27.832 carbon, 5.379 hydrogen, and 9.273 nitrogen, corresponding to the formula $C_{20}H_{25}N_2O_{32}$, but he places little confidence in these results, from the difficulty of obtaining constant combinations of emulsin. (*Ortlöff. Chem. Gaz. v. 307.*)

EMULSION. *Chem.* From *emulgeo*, to milk out. The term applies to those milky liquids procured by triturating almonds, beans, &c., with water. The mucilaginous portion of the nuts enables a suspension of a part of their oily component, and the water thus becomes turbid and whitish. In Pharmacy, emulsions are artificial unions of oil and water, rendered miscible by the intervention of mucilage.

ENAMEL. *Tech. Fr.* Email. *Ger.* Schmelzglas. The vitreous coating given to surfaces of metal either as an embellishment or a protection against the influence of corrosive reagents. The basis is an opake glass, prepared by melting 10 pts. of lead with $3\frac{1}{2}$ to 4 pts. of tin, calcining the alloy under a muffle, and fusing it with 10 pts. of pure silex and 2 pts. of carbonate of soda. Borax is frequently added. Its whitish opacity is due to oxide of tin, and may be variously tinted by the addition of other metallic colors. The fused mixture above mentioned is applied with a brush, in the state of an impalpable powder, to the surface to be enameled. The painted article is then heated in a muffle until commencing fusion of the enamel. A similar opake enamel is employed as a coating for colored earthenware, to give it the imitation of fine white earthenware.

The term enamel is sometimes, but incorrectly, given to the glazing of porcelain and fine POTTERY.

Enameled Cast-iron Vessels. The *porcelain-lined iron vessels* of extensive use in domestic economy are now made so that their inner white coating can resist the action of the fire, as well as that of acid and alkaline solutions. The first step of Clark's process is to cleanse the iron vessels, by steeping them in water sensibly acidulated with sulphuric acid for two or three hours, and afterwards washing them in boiling water. This done, they are ready to be painted interiorly to one-sixth of an inch thickness with the composition, which consists as follows: 100 lbs. calcined ground silex or flints, mixed with 50 lbs. calcined borax. Forty pounds of this mixture, after it has been fused and gradually cooled, are ground with water, and 5 lbs. of potter's clay, free from iron, to a pasty consistence. The first coat having become set by the assistance of the warmth of a heated room, it is covered by a second composition, of the following ingredients: pulverize, mix together, and vitrify 125 lbs. white glass, free of lead, 25 lbs. borax, 20 lbs. crystallized carbonate of soda. To 45 lbs. of this mixture, ground and dried, add 1 lb. of soda, and commingle the whole with hot water. Dry, and then pulverize, and with the sifted powder dust over the first coating evenly and uniformly whilst it is yet moist. The vessel now glazed is to be dried, as before, in a hot room at 212° , and then placed in a muffle, or at the mouth of a glazing-kiln, heated to full

heat, and as it gradually increases in temperature, is pushed into the interior, so as to perfect the fusion of the glaze. The enamel is improved in smoothness and hardness by a second application of the glaze-powder over the fused glaze and fluxing anew in the oven.

ENDELLIONITE. See BOURNONITE.

ENERGIATYPE. A convenient photographic process, devised by Mr. Hunt, for the fixation of objects upon sensitive paper. The rays effecting the chemical change are independent of solar light or heat. The manipulations are simple, and readily performed. The first consists in washing over good letter paper with the following mixture:—

A saturated solution of succinic acid,	2 drs.
Mucilage of gum arabic.....	$\frac{1}{2}$ "
Water.....	$1\frac{1}{2}$ "
Common salt.....	5 grs.

When the paper is dry, it is again washed with a solution of 1 drachm of nitrate of silver in 1 ounce of distilled water, and dried anew in the dark. Thus prepared, it can be laid by in a portfolio until wanted for use, as it retains its pure white color unaltered. The time of exposure in the camera, requisite to a perfect impression, varies with the intensity of the sunshine; some specimens were prepared by the inventor which required less than 30 seconds. When the paper is removed from the camera, there is no trace of the picture apparent. Another operation is requisite to develop it. Its surface must be uniformly swept over, so as to prevent spotting, with a camel's hair brush, moistened in a mixture of 1 drachm of saturated solution of sulphate of iron, and 2 or 3 drachms of the mucilage of gum arabic. A few seconds reveals a pleasingly negative photographic picture, and as soon as the best effect appears, the iron is to be washed off with a sponge and clean water, which removes all superficial blackness. If the lights become in any way discolored, a little very dilute hydrochloric acid will restore them to their proper degree of whiteness, but the acid must be instantaneously washed off, or else the shadows will be impaired. The drawing is then soaked in water for a short time, and can be permanently fixed by a wash of aqua ammoniæ, or solution of hyposulphite of soda, taking care to remove the salt afterwards by thorough soaking in water.

When, from a too brief exposure, the image is slow in developing, a slight warmth, or holding the picture near the fire, brings it out forcibly and rapidly. These pictures can be multiplied indefinitely from the same picture, and with equal perfection as to light and shadow, by exposure of the same succinated paper to sunshine for five to ten minutes.

EPIDERMIS. *Anat.* The scarf skin, or cuticle of the laminated exterior of animals and vegetables; hence its name, from *ἐπί*, upon, and *δερμα*, skin. That of animals is insoluble in water, alcohol, and dilute acids, but concentrated nitric and sulphuric acids, and the caustic alkalies, soften and ultimately dissolve it.

EPIDOTE. *Min. Syn.* Prismatoidal Augite-spar. *Mohs.* Zoisite, Pistacite, Withamite, Thallite, Acaticone, Scorza, Delphinite, Aren-

dalite, Thulite, Puschkinite, Bucklandite. Eisenepidot, Manganepidot.

Descrip. Cryst. Oblique Rhombic, combining vertical prisms, many front and back-planes, oblique side-planes, and end-planes. One perfect, and one imperfect cleavage; parallel to the latter, and to the shorter diagonal it is sometimes twinned. Also columnar and granular. H. 6—7. G. = 3—3.5. Colors various, green and gray prevailing; also white, reddish brown; lustre vitreous; generally subtranslucent, also subtransparent and opaque; brittle, with uneven fracture, and streak lighter than the solid specimen.

Chem. Relat. There are three divisions of Epidote, varying in composition, characters, and behavior. 1. *Zoisite*. Swells before the blowpipe, making bubbles, which disappear by a stronger heat; fusing on the edges to a clear, yellowish glass, forming a vitreous slag; swells up with borax, and forms a transparent glass; intumesces with mic. salt, effervesces in dissolving, and leaves a siliceous skeleton; fuses readily with a little soda to a greenish glass, but only swells with more soda, and shows manganese on platinum; gives a blue with cobalt-solution. 2. *Pistacite*. It fuses on the edges, and then swells up to a dark-brown mass, which is rounded but not wholly fused by a stronger heat; it acts like zoisite with the fluxes, but shows more iron and manganese. 3. *Manganesian Epidote*. It fuses readily with intumescence into a black glass, and behaves like the preceding to the fluxes, but shows still more iron and manganese. Nearly all epidotes give a trace of tin, with soda and charcoal, one variety from Orrijärvi, Finland, nearly 1 pr. ct. It is partially decomposed by muriatic acid, but after strong ignition, and in fine powder, readily even in the cold, with gelatinous silica. General formula, $3RO, SiO_3 + 2(R_2O_3, SiO_3)$, in which the RO is chiefly lime, partly replaced by magnesia, protoxides of iron, and manganese, and perhaps by alkali; the R_2O_3 is principally alumina in zoisite, partly replaced in the other two varieties by sesquioxides of iron and manganese.

Local. Among the numerous localities of epidote, zoisite occurs at Baireuth, Carinthia, &c.; pistacite at Arendal, Taberg, Bourg d'Oisans, Hellestad, &c.; manganesian epidote, at St. Marcel, Piedmont, &c. Thulite is from Tellemarken. Puschkinite, from Jakowleff's lands, west side of the Ural, exhibits dichroism. Bucklandite is probably a pure iron-epidote. In the U. S., at Franconia, well crystallized pistacite, and Warren, N. H.; gray columnar masses at Willsboro, at Montpelier, Vt.; Hadlyme, Chester, Newberry, Nahant, fine crystals at Athol, also at Goshen, Chesterfield, Williamsburg, &c., Mass.; at Milford, large and fine crystals at Haddam, Conn.; at Amity, Carmel, Monroe, N. Y.

EPITHELIUM. *Anat.* The cuticle of the mucous membrane.

EPSOM SALT. *Chem.* See MAGNESIUM.

EPSOM SALT. *Min. Syn.* Bitter Salt. *Ger.* Bittersalz, Haarsalz. Cryst. Right Rhombic, with one perfect cleavage; also fibrous. H. = 2.25. G. = 1.75. Color and streak

white; lustre vitreous; transparent, translucent; taste bitter, saline.

Readily and wholly soluble in water; gives neutral water in a closed tube, and fuses; soluble in borax and mic. salt, forming a cloudy bead when cold; with soda gives a hepar without fusion; with cobalt-solution gives a rosy tint. Its composition, when pure, is expressed by $MgO, SO_3 + 7HO$, to which several of the native specimens approximate.

Local. Neusohl, Hungary; Idria; Catalaynd, in Arragonia; South Africa. In U. S., in limestone caves, Kentucky, Tennessee, Indiana, with coal measures of Western Pennsylvania (*M. H. Boyé*); Heldeberg, N. Y. Epsom salt is an almost constant constituent of saline waters, some of which owe to it their taste and value.

EQUISETIC ACID. See ACONITIC ACID.

EQUIVALENTS. *Chem.* Equivalents are the proportional weights or numbers according to which, or to their multiples, bodies combine. Thus, if 1 part, by weight, of A combine with 2 pts. of B, and with 3 pts. of C; then B and C will unite in the proportion of 2 B, or a multiple of it, to 3 C, or to a multiple of it, i. e. 2 B, 4 B, 6 B, &c., to 3 C, or 6 C, or 9 C, &c. In water, 1 pt., by weight, hydrogen, A, unites with 8 pts. oxygen, B; and in sulphuretted hydrogen, the proportion is 1 pt. hydrogen to 16 sulphur, C. Then, in oil of vitriol, 16 pts. sulphur, C_1 , unite with 24 pts. oxygen, or $(3 \times 8) B_3$. One pt. hydrogen is, therefore, considered equivalent to 8 pts. oxygen, and 16 pts. sulphur. The terms atom, equivalent, combining weight, atomic weight, have been indiscriminately employed, but the terms equivalent, and combining weight, being expressions of fact, with little reference to theory, are preferable, and the former is generally used in the present work. For the difference between atom and equivalent, see ATOM; for the mode of determining equivalents, see COMBINING WEIGHT, and the former part of AFFINITY; for the equivalents of the elements, see ELEMENTS. For the equivalents of compounds, refer to those compounds under each element for inorganic bodies, and to the organic base, acid, or other organic compound, in their alphabetical place. If a formula only be given, add together the equivalent of each element in the compound, first multiplying each equivalent, or combining weight, by the number of equivalents which the formula expresses. Thus, the combining weight of sulphur being 16, and of oxygen 8, the equivalent of dry sulphuric acid, SO_3 , is $16 + 3 \times 8 = 40$, and of oil of vitriol, SO_3, HO , is $16 + 3 \times 8 + 9 = 49$. Refer also to FORMULA.

ERCRINITE. See HARMOTOME.

EREMECAUSIS. *Chem.* From *ῥέμα, οὐ* degrees, *κῆσις*, burning. A term applied to the change in form and properties which compound organic substances undergo when separated from their organism, and exposed to the influence of air, water, and a certain temperature. (*Liebig*.) It is, in other words, the gradual combination or low combustion of the elements of organic, and, especially, vegetable structures, with the oxygen of the air, attended with disengagement of heat, and, occasionally,

of light also. The temperature at which eremecausis occurs varies in different bodies, but never below 32° F. It always precedes fermentation and putrefaction, which are phenomena analogous to it, with this difference, that access of air is indispensable to eremecausis.

The substances capable of eremecausis are classified, by Liebig, into those which unite with the oxygen of the air, without evolving carbonic acid, and such as evolve carbonic acid by absorption of oxygen. Azotized bodies are the most susceptible of this change. The eremecausis of substances, rich in hydrogen, is so far similar to the putrefaction of nitrogenized bodies, that in either instance there are two affinities in action, the affinity of nitrogen for hydrogen, and of carbon for oxygen: and both facilitate the disunion of elements. The conditions determining this phenomenon are various, but the presence of decaying matter is in most instances promotive of it. It is retarded or prevented by the usual antiseptics, as the mineral acids, mercurial salts, aromatic substances, and empyreumatic oils.

The conversion of wood into *HUMUS*, the formation of *ACETIC ACID* from alcohol, and *NITRIFICATION*, are processes of this nature.

A very remarkable kind of eremecausis takes place in many vegetable substances when they are exposed to the influence of air, water, and ammonia. They absorb oxygen very rapidly, and form splendid violet or red colored liquids, as in the case of *orcin* and *erythrin*. See *Liebig's Vegetable Physiology*.

ERGOT. *Chem. Phar. Syn.* *Clavus*, Spurred Rye. *Lat.* *Secale Cornutum*. A hard, violet-black, spike-shaped grain, formed from the ovary of diseased rye that has been attacked and destroyed by fungi. Wigger's analysis, to which a later one by Chevalier is similar, gave

Ergotin.....	1.25
Peculiar fixed oil.....	35.00
White crystallizable fat.....	1.05
Cerin.....	0.76
Fungin.....	46.19
Vegetable osmazome.....	7.76
Peculiar saccharine matter.....	1.55
Gummy extractive, with red coloring matter.....	2.33
Albumen.....	1.46
Superphosphate of potassa.....	4.42
Phosphate of lime, with trace of iron ..	0.29
Silica.....	0.14

102.20

Ergotin. Syn. *Secalin*. Is the active principle of ergot, obtained by macerating the rasped grains in ether, to separate their oily and resinous portion, treating the residue with alcohol, evaporating the solution to a syrupy consistence, and adding water to precipitate the ergotin.

It is an amorphous, pulverulent, dull red substance, of a nauseous smell, and bitter acid taste; soluble in alcohol and concentrated sulphuric and acetic acids, but insoluble in water and ether. Nitric acid, aided by heat, decomposes it, without forming oxalic or mucic acid. It dissolves also in caustic potassa, but is precipitated again by the acids.

Oil of Ergot. The expressed oil is that used

in medicine. The fatty matter, extracted by ether, is resinous, and, unlike that obtained by heat or expression, is not saponifiable. Treated by potassa, glycerin is eliminated with two fatty acids, analogous to those of the fixed oils.

EREMITE. See *MONAZITE*.

ERINITE. See *BOLE*.

ERINITE. *Min.* Mammillary, crystalline groups, of a concentric fibrous structure. *H.* = 4.5 — 5. *G.* = 4.043. Emerald green, with a paler streak; lustre resinous, rather dull; subtranslucent; brittle. Behavior probably similar to olivenite, lironite, &c. According to Turner's analysis, its composition may be expressed by 5 CuO, AsO₃ + 2 HO. It occurs in Limerick county, Ireland.

EPISTILBITE. *Min.* Cryst. Right Rhombic, cleaving perfectly parallel to shorter diagonal; also granular. *H.* = 4 — 4.5. *G.* = 2.249 — 2.25. White; lustre vitreous on vert. prism, pearly on cleavage; transparent, subtranslucent; uneven fracture. Behaves like stilbite, which it closely resembles; soluble in muriatic acid, leaving pulverulent silica; after ignition, insoluble. Form. CaO, SiO₃ + 3 (Al₂O₃, 3 SiO₃) + 5 HO, with soda replacing a portion of lime.

ERYTHRIN. See *ORCHIL*.

ERYTHRITE. See *FELSPAR*.

ERYTHROLEIN. See *LITMUS*.

ERYTHROLEIC ACID. See *ORCHIL*.

ESCHSCHOLTZIA CALIFORNICA. *Chem.* Waltz has recently found three bases in the root:—1st, One soluble in water, and giving bright red crystallizable salts with acids. 2d, A colorless acrid base, soluble in ether, and forming colorless salts. 3d, A colorless base, soluble in water, alcohol, and ether. The salts of the latter are very soluble, and even in very minute proportion impart to the liquid a rich violet color upon the addition of sulphuric acid.

ESMARKITE. See *CHLOROPHYLLITE*. Its formula is the same as that of *FAHLUNITE* and *BREVICITE*, with half as much water, and with magnesia, protoxides of iron, and manganese, as the *RO* bases.

ESSENCES. } *Chem. Tech. Syn.*

ESSENTIAL OILS. } Volatile Oils, Distilled Oils, Murones. These oils are sometimes also called *essences*, but the term *essence*, properly belongs to their solution in alcohol.

The volatile or essential oils are the product of every part of plants, but not in all parts of the same plant. Sometimes they are found only in the leaves, then in the flowers, again in the rind, or the wood and fruits, and sometimes the envelopes of seeds, but not in the cotyledons. Some few plants, however, as the thyme and scented *labiate*, contain volatile oil in nearly all their parts. In some certain plants it occasionally occurs that different parts of the same contain different oils, for instance, the orange furnishes one oil from its flowers, another from the leaves, and a third from the rind or epidermis of the fruit, each varying from the other. In most plants, the oil is contained in little sacs or vesicles, so well confined that the oil is retained even during the drying of the plant and for some time after: whilst in other species, again,

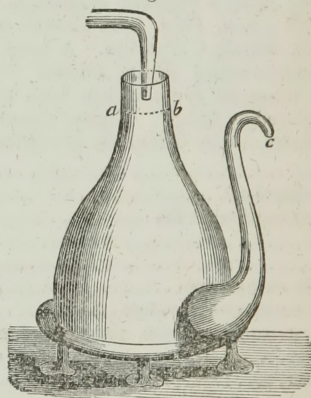
especially in the flowers, the oil is constantly produced at the surface, and escapes at the moment of its formation. A few oils are obtained by expression, such as those of oranges and lemons, where the oil resides in the epidermis of the fruit; others, again, which are not contained in vessels, such as those of violet, jasmine, &c., are procured by maceration of the flowers in oil of ben, an inodorous fixed oil, and are used in this state in perfumery. Volatile oils are distinguished from the fixed oils by their volatility, and being mostly obtained by distillation, have been called essential oils. They are considered as the source of the aroma of plants, which they diffuse by their exhalation. These oils are of an acid, burning taste, a very mild, agreeable, a pungent, or an unpleasant odor; mostly colorless, when properly rectified, but, as found in commerce, some are yellow, some red or brown, and others, again, green, and a few blue; and, with few exceptions, are lighter than water. They are not greasy to the touch, and their specific gravity ranges between 0.759 and 1.096; the first number denoting the density of oil of coriander, and the second, that of oil of sassafras. Most of them congeal at different temperatures; some acquire viscosity at the ordinary temperature of the atmosphere and become solid. They burn with a brilliant flame and much smoke. Although they are styled volatile oils, the tension of their vapor, as well as its specific heat, is much less than that of water, and though volatile at the ordinary temperatures, their boiling point usually is not less than 316° to 320° . It varies in different oils, and this distinctive property serves as a characteristic, and, under some circumstances, to isolate them.

In contact with air or oxygen, they acquire thickness, and are eventually converted into a resin by the absorption of that gas. Indeed, they naturally exist in some instances combined with resins and balsams, both, frequently, originating either from the hydration or oxygenation of a portion of the oil. The absorption of oxygen varies with different oils, and gives rise to carbonic acid gas, but no water is formed. Light contributes powerfully to this action. A volume of concrete oil of anise absorbed 159 times its volume of oxygen gas in two years, and emitted, at the same time, 56 volumes of carbonic acid gas. A volume of oil of lavender, during four of the colder months, absorbed 52 volumes of oxygen, and gave out two of carbonic acid gas, without the production of water, and without being even yet completely saturated with oxygen. These facts are stated upon the authority and results of Saussure's experiments. "It has been observed, that the odor of oils is closely related with this chemical change. Those which oxidate most rapidly have the strongest smell, and the characteristic odor of no oil can be perceived, immediately after its distillation, in an atmosphere of carbonic acid gas."

Prep. The few oils existing in the rind of fruits are obtained by expression, but of inferior quality. The best mode of preparation is that of distillation, the only method appli-

cable to the separation of the majority of them. The requisite apparatus is a copper still, enclosing a wicker fender, and the material being heated therein with water, parts with its volatile portion, which passes over in the state of vapor with the water, and, upon congelation, separates into an oily layer, occupying the lower or upper stratum in the recipient, according as its density is greater or less than that of water. Although the boiling point of the oil is higher than that of water, under most circumstances, yet their vapours become involved and pass over together, and for the reason, that water, in its attenuated state and elevated temperature, dissolves the gaseous oils, as it were, for the time being, and drops them, upon an appreciable abstraction of heat. For the less volatile essences, those requiring a more elevated temperature than 212° F. for their elimination, the point of ebullition of the concomitant water should be increased by the addition of some salt. To entirely exhaust some plants of their oil, it is necessary to cohobate repeatedly with the same water. A like necessity occurs with those plants meagre in volatile component, but in such instances, the cohobation must be over fresh material. For conveniently separating the lighter oil from the water which passes over with it, a Florentine glass, of suitable form, is generally used as their recipient. The oil accumulating at *a b* (fig. 69), and occupy-

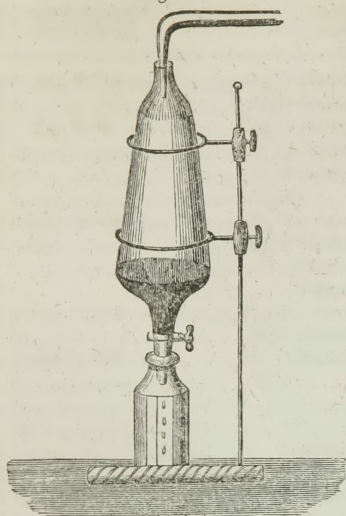
Fig. 69.



ing the upper stratum, retains its position, while the water beneath escapes at *c*. When the oil is heavier than the water, a different arrangement must be adopted, as is shown by fig. 70. The receiver for this purpose must be cylindrical, and funnel shaped at the bottom, with a stopcock in its barrel, so that the heavy oil can be drawn off as it collects.

Comp. Most of the essential oils exist, already formed, in the plants, as secreted by their proper organs, whilst a few are generated only by distillation, and take their rise during a kind of fermentation. As examples of these latter, we treat under their proper heads, of the oils of mustard seed and bitter almonds. The essential oils are divided into three classes, those containing only carbon and hydrogen, those containing also oxygen, and those containing sulphur. Another characteristic of essential oils is, that some, by a direct absorp-

Fig. 70.



tion of oxygen, become acidified, and others, again, by a more indirect application of the same gas, become resinous. Experience has demonstrated, that most of the essential oils consist of two oils, both fluid, and of different volatility, or one solid and the other fluid at common temperature or below it, but these constituents have no analogy whatever to the olein and stearine of the fixed oils. Bizio called these principles *sèreusine* and *igrusine*, or, in more modern language, *elaopten* and *stearopten*; the latter of which is separable from the former by pressure, when the oil is congealed at a sufficiently low temperature. Sometimes the two components are liquid, and being of different boiling points, are separable by properly managed distillation. As a general rule, the solid principles are oxygenated and the liquid mostly carbo-hydrogens. The oil of camphor, and essence of lavender, are, however, exceptions. If the analyses of the essential oils are compared with those of the fixed oils, the difference in their constitution will appear evident, for, whilst the former are richer in carbon, many of them are much more deficient in oxygen, some even entirely destitute of it, and a few, as said above, contain a little sulphur, and, according to some chemists, nitrogen also. The proportion of hydrogen varies in different oils, but, as a general rule, they are more hydrogenated than the fixed fats. The source whence is obtained the gaseous components of these oils, and, as a consequence, the nourishment of the plants which yield them, is the atmosphere, for the carbon and nitrogen; water, for the hydrogen; and sulphuric acid for the sulphur; all of which are withdrawn from the surrounding media containing them by the vegetable organism, and assimilated as above. Containing little or no oxygen, they have been evidently subjected to a great degree of reduction.

The *stearopten*, or crystallizable portion of those oils, thus constituted, is commonly called the *camphor* of the plant, and not unfrequently forms artificially, when the oils are in contact with water.

As regards the camphors of the oils, they vary in properties, some containing only carbon and hydrogen, and others, these two ingredients, and oxygen additional, the *stearopten* of the otto of rose being an example of the former. The *stearopten* is generally very fusible, and seldom retains its solidity beyond 68°.

The essential oils are but little soluble in water; alcohol, ether, and the fixed oils, however, dissolve them readily.

Chlorine, bromine, iodine, cyanogen, and fluorine act by displacing the hydrogen. The first three, in rare instances, form direct combinations.

Potassium displaces in some oils, one atom of their hydrogen, but only deoxidizes those whose oxygen belongs to the combined water.

The oxidizing agents (chromates, manganates, &c.), aided by sulphuric acid, convert these oils into hydrates. The more recent experiments of Persoz show, that the oxidizing effect of chromic acid upon essential oils transforms them into new products; thus, for instance, from fennel and anise oils he obtained acetic acid, and two other acids, sparingly soluble. One, the *umbellie*, closely allied to benzoic, is separable from the other (*badi-anic*) by cold ether, which dissolves the latter. In like manner the oil of cumin is converted into acetic acid, and two crystallizable, differently soluble acids (*cyminic* and *cuminic-cuminic*); the oil of cinnamon into acetic and benzoic acids. Oil of tansy, similarly treated, gave a considerable quantity of common camphor.

Concentrated nitric acid acts violently, and sometimes with explosion. When diluted, and aided by heat, it transforms the essences into peculiar crystallizable acids. In this action of dilute nitric acid upon essential oils and resins, Sobrero says, there is generated an appreciable quantity of prussic acid, which is given off when the oil has thickened. Monohydrated sulphuric acid gives rise to complicated bibasic salts (sulfo-murones), analogous to the sulfo-vinates. *Baudrimont*.

The small portion of nitrogen occasionally found in some of the oxy-oils, is probably owing to azotized impurity.

Carbo-hydrogens. The oils of this group, with one or two exceptions, are simple carbo-hydrogens, and are remarkable for being uniformly of the formula (C_5H_4), or one expressing some multiple of these numbers, and even those which differ from this formula, may, upon closer examination, be found to belong to another class of oils. There are several modifications of oil of turpentine, which have the same composition as that oil, but differ in their relations to polarized light, and in some other respects. See *CAMPHINE*. There being some difficulty in ascertaining the boiling points of the essential oils, the degrees given in the annexed table cannot be regarded as definitely fixed, although they are not far from the truth.

The composition of some of these oils has not been determined with accuracy, but the annexed table comprises the greater part of those which belong to the non-oxygenated class of essential oils, of which those of turpentine, lemons, camphor, and copaiva have been most fully investigated.

ESSENTIAL OILS.

ESSENTIAL OILS.

Names of the Oils.	Botanic Names of the Plants from which extracted.	Spec. Grav.	Formulæ.	Circular Polarizing Power.	Boiling Point.
Oil of Turpentine....	<i>Pinus sylvestris</i>	0.864	$C_{20}H_{34}$	— 43° 3' left.	315°F
" Pine top	" <i>Abies</i>	0.856	$C_{20}H_{34}$ .....	.....	333°
" Juniper	<i>Juniperus communis</i>	0.839	C_5H_8	— 3° 5' left.	311°
" Sabine	" <i>Sabina</i>	0.915	C_5H_8 .....	.....	315°
" Elemi	<i>Amyrus Elemifera</i>	0.852	C_5H_8 .....	.....	330°
" Storax	<i>Storax liquidi</i> .....	.....	C_5H_8 .....	.....	.....
" Lemons	<i>Citrus Limonum</i>	0.855	C_5H_8	+ 80° 9' right	343°
" Oranges	" <i>Aurantium</i>	0.835	$C_{10}H_{16}$	 right	356°
" Neroli	" " (flowers) ..	0.930	.....	.....	.....
" Portugal	" " (peel)	0.835	.....	.....	356°
" Copaiva	<i>Copaifera multijuga</i>	0.96	$C_{10}H_{16}$	— 34° 3' left.	473°
" Pepper	<i>Piper Nigrum</i>	0.864	C_5H_8 .....	.....	333°
" Cubebs	" <i>Cubeba</i>	0.929	$C_{15}H_{24}$	— 40° 1' left.	490°
" Cedrat	<i>Citrus medica</i> .....	.....	C_5H_8 .....	.....	.....
" Bigarade	" <i>bigarea</i> .....	.....	.....	.....	.....
" Petit-grain ....	" " .....	.....	.....	.....	.....
" Amber(rectif'd)	<i>Succinum</i>	0.879	$C_{14}H_{22}$ ? .....	.....	266°
" Namur	<i>Andropogon Ivaracusa</i> .....	.....	C_5H_8 .....	.....	297°
" Cedar (liquid) ..	<i>Juniperus Virginiana</i>	0.98	$C_{32}H_{54}$ (?) .....	.....	507°
" Athamanta	<i>Athamanta oreoselinum</i>	0.843	$C_{20}H_{34}$ .....	.....	325°

Oxygenated Oils. The oxy-oils, when distilled with anhydrous phosphoric acid, generally lose oxygen and hydrogen in the proportions which constitute water, and give rise to carburets of hydrogen, whose names terminate in *en*, as menthen, cedren, &c.

Distilled upon anhydrous baryta, the result is a carbonate and a less oxygenated product, of formula the same as its derivative oil, minus carbonic acid. The termination of its

title is in *one*, as campholone, or sometimes in *ole*, as anisole.

The action of lime, potash, and soda differs according as they are hydrated or anhydrous. Gerhart and Cahours aver, that most of the oxy-oils are, by the action of fused hydrate of potassa, separable into an acid, and an oil destitute of oxygen.

Below is a table of the most important oxy-oils.

Names of the Oils.	Botanic Names of the Plants from which extracted.	Spec. Grav.	Formulæ.	Circular Polarizing Power.	Boiling Point.
Oil of Cinnamon	<i>Laurus Cinnamomum</i>	1.03	$C_{20}H_{31}O_2$ .....	.....	.....
" Cassia	" <i>Cassia</i>	1.09	$C_{20}H_{31}O_2$ .....	.....	.....
" Cloves	<i>Caryophyllus aromaticus</i>	1.60	$C_{24}H_{35}O_5$ .....	.....	470°
" Sassafras	<i>Laurus Sassafras</i>	1.08	$C_{10}H_{15}O_2$ .....	.....	257°
" Sweet-bay	" <i>nobilis</i>	0.914	$C_{20}H_{31}O$ .....	.....	.....
"	<i>Pichurium</i> .....	.....	.....	.....	.....
" Culiliban	" <i>Culiliban</i> .....	.....	.....	.....	.....
" Chervil	<i>Scandix cerefolium</i> .....	.....	.....	.....	.....
" Saffron	<i>Crocus Sativus</i> .....	.....	.....	.....	.....
" Limette	<i>Citrus limetta</i>	0.931	.....	+ 29° 3' right	.....
" Bergamot	" <i>Bergamotta</i>	0.856	$C_{30}H_{46}O_2$	 right	361°
" Roses	<i>Rosa centifolia</i>	0.832	.....	.....	.....
" Rhodium	<i>Convolvulus Scoparius</i> .....	.....	.....	.....	.....
" Rose-geranium ..	<i>Pelargonium radula</i> .....	.....	.....	.....	.....
" Cajeput	<i>Melalencia Cajeputi</i>	0.978	$C_{10}H_{16}O$ .....	.....	347°
" Semen-contra ..	<i>Artemisia Castra</i>	0.936	$C_{18}H_{26}O_2$ .....	.....	.....
" Wormwood	" <i>Absinthium</i>	0.897	$C_{20}H_{32}O_2$ (?) .....	.....	356°
" Tarragon	" <i>Dracunculus</i>	0.945	$C_{24}H_{36}O_2$ .....	.....	391°
" Mugwort	" <i>vulgaris</i> .....	.....	.....	.....	212°
" Cherry-laurel ..	<i>Prunus laurocerasus</i> .....	.....	.....	.....	.....
" Bird cherry ...	" <i>Padus</i> .....	.....	.....	.....	.....
" Peach-kernel ..	<i>Persica vulgaris</i> .....	.....	.....	.....	.....
" Bitter almond ..	<i>Amygdalus communis</i> .....	.....	.....	.....	.....
" Aspic	<i>Spica latifolia</i> .....	.....	.....	.....	.....
" Basil	<i>Ocymum basilicum</i> .....	.....	$C_{20}H_{32}O_6$ .....	.....	.....
" Cat-thyme	<i>Teucrium Marium</i> .....	.....	.....	.....	.....
" Yarrow	<i>Achillea Millefolium</i>	0.92	.....	.....	.....
" Zedoary	<i>Curcuma Zedoaria</i> .....	.....	.....	.....	.....
" Calamus	<i>Acorus Calamus</i>	0.962	.....	.....	.....
" Valerian	<i>Valeriana officinalis</i>	0.944	$C_{12}H_{20}O_2$ .....	.....	392°
" Camphor	<i>Dryobalanops aromatica</i>	0.945	$C_{20}H_{32}O$		
" Cascarilla	<i>Croton Eleuteria</i>	0.938			

ESSENTIAL OILS.

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Names of the Oils.	Botanic Names of the Plants from which extracted.	Spec. Grav.	Formulae.	Circular Polarizing Power.	Boiling Point.
Oil of Tansy	Tanacetum vulgare.....	0.931			
" Parsley	Apium petroselinum		$C_{12}H_8O_3$		410°
"	Genista Canariensis.....				
" Water-fennel..	Phellandrina Aquaticus.....				
" Ginger.....	Amomum Zingiber.....				
" Caraway.....	Carum Carui.....	0.938			401°
" Cumin.....	Cuminum Cyminum.....	0.860	$C_{20}H_{12}O_2$		418°
" Coriander.....	Coriandrum Sativum.....	0.759			
" Pimpernel....	Pimpinella Saxifraga.....				
"	" magna				
" Peppermint ...	Mentha piperita	0.917	$C_{24}H_{20}O_2$		
" Pennyroyal ...	" Pulegium.....	0.925	$C_{10}H_8O$		395°
" Spear-mint....	" viridis	0.914	$C_{35}H_{28}O$		331°
" Curled-mint...	" crispa	0.969			
" Horse-mint....	Monarda punctata				
" Sw't-marjoram	Origanum Marjorana				
" Dittany	" Creticum.....	0.946			
" Marjoram.....	" vulgare	0.867	$C_{50}H_{40}O$		354°
" Balm	Melissa officinalis	0.975			
" Lavender	Lavandula Spica.....	0.872	$C_{15}H_{14}O_2$ (?)		365° ?
" Rosemary.....	Rosmarinus officinalis	0.897	$C_{40}H_{38}O_2$		365°
" Thyme.....	Thymus vulgaris	0.905			
" Serpolet.....	" Serpyllum				
" Rue.....	Ruta Graveolens.....	0.837	$C_{25}H_{28}O_3$		446°
" Wild cham'mile	Matricaria Chamomilla	0.924			
" Chamomile ...	Anthemis nobilis	0.908			
" Tea.....	Thea viridis				
" Angelica.....	Angelica Archangelica.....				
" Sage.....	Salvia officinalis.....	0.905			
" Hyssop.....	Hyssopus officinalis				325°
" Horehound....	Lycopus Europæus				
" Marsh-ledum..	Ledum palustre.....				
" Wintergreen ..	Gaultheria procumbens.....	1.18	$C_{16}H_{18}O_6$		435°
" Ulmaria	Spiræa Ulmaria	1.173	$C_{10}H_9O_2$		380°
" Lycian Juniper	Juniperus Lycia.....	0.866	$C_{32}H_{26}O$		323°
" Spanish Juniper	" Thurifera.....				
" Myrrh.....	Balsamodendron Myrrha.....				
" Galbanum.....	Galbanum officinale.....	0.92			
" Sagapenum	Ferula Persica				
"	Cupressus Sempervirens.....				
" Thuja (Amer'n)	Thuja occidentalis.....				374°
" Serpentaria ..	Aristolochia Serpentaria				
" Brasileto	Cæsalpina Crista				
"	Hedwigia balsamifera	0.847			313°
" Birch	Betula alba.....				
" Sweet-birch ...	" lenta	1.173			
" Winter-bark ..	Wintera aromatica				
" Black-poplar ..	Populus Nigra.....				
" Wormseed	Chenopodium Anthelmintic'm	0.908			
" Ginger.....	Zingiber officinale				
" Parmelia(wall)	Parmelia Parietina.....				
" Lime-tree	Tilia Europæa.....				
" Elder	Sambucus niger				
" Reseda.....	Reseda odorata				
" Syringa.....	Philadelphus Coranarius				
" Lilac	Syringa vulgaris				
" May-lily	Convallaria majalis.....				
" Buchu	Diosma crenata				
" Sweet-gale	Myrica Gale.....	0.876			
" Nutmeg.....	Myristicha Moschata.....	0.92			
" Mace	"				
" Galangal.....	Maranta Galanga.....		$C_{10}H_9O$		
" Alpinia	"				
" Cardamom	Amomum repens.....	0.945			
" Anise.....	Pimpinella Anisum.....	0.985	$C_{20}H_{12}O_2$		
" Badian.....	Illicium Anisatum.....	0.987			
" Dill.....	Apium Graveolens	0.881			

ESSENTIAL OILS.

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Names of the Oils.	Botanic Names of the Plants from which extracted.	Spec. Grav.	Formulae.	Circular Polarizing Power.	Boiling Point.
Oil of Fennel.....	Anethum Fœniculum.....	0.997	$C_{20}H_{12}O_2$.....	.....	.....
“ Orris	Iris Florentina.....	.....	.....	.....	.....
“ Pimento	Eugenia pimenta.....	1.021	.....	.....	.....
“ Asarabacca ...	Asarum Europæum.....	.....	C_8H_4O.....	.....	.....
“ Castor	Castoreum Rossicum.....	.....	.....	.....	.....
“ Cedar (solid)..	Juniperus Virginiana.....	.....	$C_{30}H_{26}O_2$.....	.....	540°
“ Tonka	Dipterix Odorata.....	.....	.....	.....	.....

The Sulphuretted Oils. A distinctive peculiarity of these oils is their diffusive aliaceous odor. Sulphur, in their composition, takes the place of oxygen, and they are related,

doubtless, to other groups not yet determined.

Annexed is a table of the principal oils of this class.

Names of the Oils.	Botanic Names of the Plants from which extracted.	Spec. Grav.	Formulae.	Circular Polarizing Power.	Boiling Point.
Oil of Black Mustard	Sinapis nigra.....	1.038	$C_8H_5NS_2$.....	.....	298°
“ Horse-radish ..	Cochlearia Armoracea.....	1.01	$C_8H_5NS_2$.....	.....	.....
“ Cochlearia	“ officinalis.....	.....	$C_8H_5NS_2(?)$.....	.....	318°
“ Garlic	Alium Sativum.....	.....	C_6H_5S.....	.....	.....
“ Onions.....	“ Ceba.....	.....	.....	.....	.....
“ Assafœtida....	Ferula Assafœtida.....	0.942	.....	.....	326°
“ Water-pepper .	Polygonum Hydropiper.....	.....	.....	.....	.....
“ Wake-robin....	Arum Maculatum.....	.....	.....	.....	.....
“ Lepidium	Lepidium latifolium.....	.....	.....	.....	.....
“ Hops	Humulus Lupulus.....	0.910	.....	.....	.....
“ Alliaria.....	Erysimum alliaria.....	.....	.....	.....	.....

Practical Application. The majority of these oils are only useful for flavoring or aromatizing. Some few are applicable to medicinal purposes, and one or two are employed in the arts. They have no positive affinity for alkaline bases, and are therefore only useful, in soap making, to impart a perfume. A sort of feeble combination may, with time and difficulty, be effected between caustic alkali and the oils of cloves, cinnamon and cedar wood. The products are styled “*Savonules*.”

That soap called Starkey’s, may be classed under this head. It consists of soda and essence of terpentine. It is prepared by triturating recently fused caustic soda in a mortar with a little oil of terpentine, added dropwise, until the mixture has acquired the consistence of soap. The compound is to be dissolved in spirits of wine, filtered and distilled. What remains, after the spirit is drawn off, consists of soda combined with a resin formed in the oil during the act of trituration.

Adulterations. The most prevalent adulterations are fat or fixed oils, resins, balsam copaiva, and spirits of terpentine. Either of the first three may easily be detected, by putting a drop of the oil on paper, and heating it, for, if pure, it will evaporate, without leaving any stain or residuum, whilst an oil, mixed with any one of them, leaves a translucent spot upon the paper. The presence of alcohol, which is also sometimes used to sophisticate essential oils, is recognised by their being less odorous, and more fluid. It is, however, difficult to detect it with accuracy. One method is to pour a portion of the suspected

essence in a graduated glass tube of determined length, and agitate it with water charged, but not saturated, with common salt. The water abstracts the alcohol, and the additional space then occupied will determine the proportion of the adulterating liquid.

Borsarelli proposes chloride of calcium as a test for the presence of alcohol. Perfectly dry chloride of calcium dissolves in oils containing alcohol, and forms a liquid stratum at the bottom of the vessel. When but little alcohol has been mixed with them, the pieces change, at least with regard to their form, but in pure oils the chloride of calcium remains unaltered. *Archiv. de Pharm.*, xxiv.

A few years since, Mero discovered a process for detecting the presence of spirits of terpentine, founded on the circumstance that this oil dissolves the fixed oils with great facility; while the essential oils, above mentioned, do not. He considers, therefore, that it will serve to indicate the presence of oil of terpentine, mixed with pure essential oils, whose powerful smell conceals that of the terpentine. Experience gives the preference to the oil of poppies, for this purpose, because of its uniform consistence, regardless of temperature. About three grammes of oil of poppies are poured into a graduated tube, and an equal quantity of the essential oil to be tested added; the mixture is then shaken, and should become of a milky white, if the essential oil is pure, whilst it remains transparent, if it contain any oil of terpentine.

The value of this method may readily be ascertained, by first testing a pure essential

ETHAL.

oil, and then some essential oil of terpentine; if the essential oil is then mingled with the oil of terpentine, even in proportions so small that no advantage could accrue to traders by the admixture, it is found to act like the essential oil of terpentine itself, that is to say, the mixture is not rendered turbid.

To make the experiment successful, the two essential oils should be very intimately blended. The method employed in commerce for this purpose is as follows:—The pure essential oil and the quantity of oil of terpentine which is to be added to it, are placed in a hot water bath-basin, and this is heated until the mixture, which is at first turbid, becomes transparent. The medley, which is obtained by adding oil of terpentine in the process of distilling the plants, is detected in the same manner. This process, though available for the detection of adulteration in several of the essential oils most in use, is, however, not of general application, for it furnishes no proof of the presence of essence of terpentine in the oils of thyme and rosemary.

M. Voget considers concentrated sulphuric acid as the best reagent for detecting adulterations of essential oils, with oil of terpentine.

ETHYL.

The peculiar color which the former assumes with sulphuric acid, is much altered by the intense reddish brown color which the oil of terpentine yields; and, moreover, the heat evolved with the oil of terpentine, is greater than that with other oils. In testing, the oils are best dropped upon a glass plate, beneath which is placed a piece of white paper; five drops of the oil are then added to one drop of fuming (*Nordhausen*) sulphuric acid, and the two are mixed with a glass rod.

Violet and Guenaud, perfumers in Paris, announced, some years since, an instrument for estimating the value of the essential oils by their specific gravity. It is merely a very sensitive areometer, which, by means of a small weight, was rendered proper for testing those oils heavier than water, and without the weight, for such as are lighter than water. Bussy and Chevalier, who reported favourably upon this instrument, verified its exactness by experiments, but specific gravity is not always a reliable test.

Below is a table of concrete, crystalline, volatile principles of plants, which are analogous to the essential oils, and, like them, can be extracted by distillation with water.

Names.	Botanic Names of Plants.	Spec. Grav.	Formulae.	Boiling Point.
Nicotianin.....	Nicotiana tabacum.....	....	$C_{24}H_{16}NO_3(?)$ ..	....
Asarin	Asarum Europæum.....	0.95	$C_{16}H_{11}O_4$	536°
Anemonin	Anemone pulsatilla .....	....	$C_5H_2O_2$ .....	....
Helenin	Inula helenium .....	....	$C_{14}H_9O_2$	530°
Quassian	Quassia amara .....	....	.....	....
Vanillin	Epidendron Vanilla .....	....	.....	....
Tanguin	Tanghinia Madagascariensis ..	....	.....	....
Cantharadin	Lytta ruficollis.....	....	$C_{10}H_6O_4$ .....	....
Primulin.....	Primula auricula .....	....	.....	....

ETHAL. See CETYL.

ETHOGEN. *Prep.* Heat to redness in a brasked crucible 7 pts. finely powdered anhydrous boracic acid, and 9 pts. melone; or, ignite 5 pts. sulphur, 58 pts. cyanide of mercury, and 7 pts. anhydrous boracic acid.

Prop. A white powder, evolving ammonia by exposure to air, or much more by heating with hydrate of potassa; burns rapidly before the blowpipe, giving a green color, without phosphorescing. Ethonide of potassium is made by igniting 7 pts. boracic acid and 20 pts. cyanide of potassium in a brasked crucible, or by directly heating ethogen and potassium. Other metallic ethonides are prepared by heating together sulphur, cyanide of mercury, boracic acid, and the metallic sulphuret. Ethogen contains boron and nitrogen. (*Balmain.*) Accurate chemical investigation is wanted to ascertain the nature of these bodies.

ETHYL. *Syn.* Aethyl, Ethule. The assumed radical of a series of compounds derived from alcohol, composed according to the formula C_4H_5 , the oxide of which, C_4H_5O , is oxide of ethyl, or common ether, and, according to most chemists, alcohol is the hydrated oxide, C_4H_5O , HO ($C_4H_5O_2$, or C_2H_3O). Although Berzelius gives good reasons for not considering alcohol as hydrated ether, and

writes as its formula C_2H_3O , yet the formation of alcohol in many decompositions of ethylic bodies is so like the precipitation of a hydrated metallic oxide, that we may view it as hydrated oxide of ethyl. A former view, still followed in France, was that ether was the hydrate of ethen (etherole), C_4H_4HO , and alcohol its bihydrate. This view is favoured by the fact, that compounds, C_4H_4 , have been isolated, and may be obtained from many ethylic compounds; and it is probable, that ethen, C_4H_4 , demands an equiv. of water to form the oxide of a radical, C_4H_5O , just as ammonia, NH_3 , requires HO to form oxide of ammonium, NH_4O .

The difference of these views is unimportant at present, but it does seem more convenient to regard ether as a basic oxide, since it forms numerous compounds, resembling both amphiid and haloid salts.

ETHYL, AND ITS SIMPLE COMPOUNDS.

1. *Ethyl.* *Form.* C_4H_5 . Not isolated.

2. *Ether.* *Syn.* Oxide of Ethyl, Sulphuric Ether, Hydrate of Ethen. *Form.* C_4H_5O , or C_4H_4HO . *Sym.* E.

Prep. 1. Pour 1 pt. alcohol, of 0.83, into a capacious retort, let a fine stream of 1 pt. oil of vitriol (1.85), flow into the retort, kept in

agitation, and attach a well-cooled recipient to the retort, which is set in a warm sand-bath. The temperature rises by the mixture to 160° , and by maintaining gentle ebullition, the ether condenses in the recipient; whereas, by first cooling the mixture, a large portion of alcohol would pass over unchanged.

2. Five pts. alcohol, of .822 (90 pr. ct.), are mixed in a cooled vessel with 9 pts. oil of vitriol, and introduced into a glass retort or lead-still. A tube is passed into the retort, so that its end, drawn out finely, dips slightly beneath the surface of the liquid, while the other end is connected with a reservoir of alcohol of the above strength. The retort is slowly heated to, and maintained at, ebullition, and as the ether and water pass over, alcohol is suffered to flow in to keep the liquid at the same height. In the leaden still, the proportion of alcohol allowed to flow in is estimated by experience. The ether is passed through a tube or worm, kept well cooled; on a small scale, a condenser (DISTILLATION, fig. 53) is conveniently employed, and the use of ice for cooling is economical.

To obtain ether pure, repeated distillation with lime and chloride of calcium are necessary, the best plan being to mingle the crude distillate with milk of lime and an equal volume of water, which separate acid and alcohol, to draw off the lighter liquid, to digest it for some time with chloride of calcium or quick lime, and, finally, to rectify it with one of the two last substances.

Theory of the Ether Process. Beside oil of vitriol, phosphoric and arsenic acids, terfluoride of boron, chloride of zinc, tin, and other chlorides, effect a similar transformation or decomposition of alcohol; and from the known affinity of these substances for water, it might be supposed that the decomposition is due to this property, since alcohol, less water, = ether; but, 1, there are other substances with a strong affinity for water, which do not affect the same change; and, 2, the decomposition with sulphuric acid is found to be more complex. The acid catalyses alcohol, forming sulphovinic acid, and a more hydrated sulphuric acid, and, at a proper temperature, the sulphovinic acid boils by its decomposition with the escape of ether. Oil of vitriol, diluted with 55 pr. ct. water, forming $\text{SO}_3\text{HO} + 3\text{HO}$, does not decompose alcohol at ordinary temperatures, but does so when the mixture boils. When equal pts., by weight, of oil of vitriol and alcohol are heated to boiling, and saturated at this temperature with milk of lime, filtration separates sulphate of lime from the solution of sulphovinate of lime; but if the mixture were cooled or diluted before the saturation, the quantity of sulphovinate obtained is less, alcohol being reproduced. As free alcohol is decomposed by chlorine, and the sulphovinates are not, and since the above product is not decomposed by chlorine, it would seem that all the alcohol is decomposed, and constitutes, with lime, the sulphovinate of lime. When 100 pts. oil of vitriol are mixed with 55 pts. of alcohol, of 85 pr. ct., the mixture contains the elements of 1 eq. sulphovinic acid, and 3 eq. water; and when this mixture

is heated above 284° , the sulphovinic acid, which is actually formed, is decomposed into ether and water, which pass over about in the proportion in which they exist in alcohol. The addition of sulphuric acid to the mixture raises the boiling point and retards the escape of ether. It appears that the water present is essential, and expels the ether by assuming its place in the ethylic compound; but if more water be used, so as to bring the boiling point of the mixture below 259° , alcohol alone passes over. If the sulphuric acid be mixed with excess of alcohol, the latter passes over until the boiling point rises to 259° , when ether begins to distil over, but the greater part passes over between 284° and 302° . At 320° , sulphurous acid begins to form, but ether still distills off, although constantly diminishing to near 400° . The catalysis of alcohol is different at these higher temperatures, elayl, &c., being formed. It appears, then, that a certain mixture of alcohol, sulphuric acid, and water, maintained at and above 284° , is first resolved into sulphovinic acid, and 3 eq. water, that this is decomposed into ether and water, which pass over, and oil of vitriol with 3 eq. water, which remains; that new portions of alcohol introduced into the acid are similarly resolved, so that there appears to be no limit to this catalytic action of oil of vitriol + 3 eq. water. In fact experience has shown, that on a manufacturing scale, a small quantity of oil of vitriol serves to produce a large amount of ether, and that even then, the remaining acid may be used for other purposes.

Properties of Ether. Ether is a colorless, transparent, thin-flowing liquid, of a peculiar penetrating aromatic odor, a sharp and aromatic taste; spec. grav., at 68° , 0.7155 (*Saussure*), 0.7154 compared with water of greatest density (*Gay-Lussac*), 0.713 (*Dumas* and *Boullay, jr.*). It is one of the most volatile liquids, boiling at 96.2° (Bar. 0m.76), *Gay-Lussac*, 93.2° (Bar. 0m.745), *Dumas*, in consequence of which it evaporates rapidly, producing a considerable degree of cold, so that water may be frozen by its more rapid evaporation under the air-pump; the tension of its vapor, at 64.4° , is 0m.38, or $\frac{1}{3}$ the barometric column; the gas weighs 2586 (air = 1000), *Gay-Lussac*, by theory 2564, consisting of 8 vols. of carbon vapor, 10 vols. hydrogen, and 1 vol. oxygen condensed into 2 vols.

Ether mixes with alcohol in all proportions, but may be separated again by agitation with 2 vols. water; it is soluble in 9 pts. water, and the solution has a spec. grav. 0.95; on the other hand, 1 pt. water is soluble in 36 pts. ether; it dissolves $\frac{1}{80}$ of sulphur, and $\frac{1}{34}$ of phosphorus, and each may be obtained in crystals from the solution; it dissolves many salts; it is useful for dissolving organic bodies, certain acids, alkaloids, oils, resins, wax, &c., but its solvent powers are in general less than those of alcohol, and hence affords a mean of separating bodies from each other.

Ether left a long time in contact with water, is converted into alcohol, by absorbing an eq. of water; by the action of air ether is converted into acetic acid and water more readily

at higher temperatures, and still more rapidly by the presence of alkali; ether absorbs ammonia in large quantity; lead, iron, zinc, &c., oxidize slowly under ether, forming acetates; potassium and sodium slowly evolve hydrogen from it; ether absorbs chlorine, dissolves bromine and iodine, forming compound ethers and hydracids; oil of vitriol, with ether in equal parts, yields, at 133°, oil of wine, olefiant gas, acetic acid, and water; with nitric acid, there result carbonic, acetic, and oxalic acids; ether dissolves nitric oxide, cyanogen, cyanhydric, and chlorohydric acids, and a saturated solution of the last yields, by distillation, chlorohydric ether.

Ether burns readily, with a clear, white flame, being converted into carbonic acid and water, and from its volatility, its explosive nature, when mingled with air, demands care in its preparation and use. By low combustion (APHLOGISTIC LAMP), it forms a very acrid vapor, containing acetic, formic, and aldehydic acids. When passed through an ignited tube of glass or porcelain, it is resolved into hydrocarbons, oxycarbons, aldehyde, and other products, not closely studied, the nature and proportions of which vary with the temperature.

3. *Alcohol*. Syn. Hydrate of oxide of Ethyl, Bihydrate of Ethen. See ALCOHOL.

4. *Chloride of Ethyl*. Syn. Muriatic or Chlorohydric Ether. Ger. Aethylchlorür, Leichter Salzäther. Form. ECl ($\text{C}_2\text{H}_5\text{Cl}$). Prep. Distil, 1, alcohol saturated with chlorohydric gas; 2, equal vols. alcohol and strong muriatic acid; 3, alcohol, with dry chlorides of tin, bismuth, arsenic, antimony, zinc, &c.; 4, one pt. oil of vitriol, with 1 pt. alcohol and 2 pts. common salt. The most important point, its condensation, must be effected by ice, or ice and salt, as this ether is gaseous at summer temperatures. A convenient arrangement is to pass the gas from the retort into a flask of water, which retains alcohol and acid, and then through an inverted syphon, placed in a cylinder filled with ice and salt. It should also be digested with chloride of calcium in ice-cooled vessels.

Prop. Muriatic ether is colorless, with a strong, penetrating, ethereal, slightly garlick odor and taste; of spec. grav. 0.869, at 32°; very volatile, boiling at 54°; spec. grav. of gas = 2.219; soluble in 24 pts. water, and the solution is neutral to litmus, and does not precipitate nitrate of silver; soluble in alcohol in every proportion; dissolves sulphur, phosphorus, oils, &c., like ether. It is decomposed by chlorine, sulphuric and nitric acids, slowly by alkalis, forming chlorides. Suffered to escape from a fine opening it burns with an emerald-green, from a larger opening with a yellowish green, smoky flame. Passed through a porcelain tube at low ignition, it is resolved into equal volumes of chlorohydric and olefiant gases.

5. *Bromide of Ethyl*. Bromohydric Ether. Form. EBr ($\text{C}_2\text{H}_5\text{Br}$). Prep. By distilling 40 pts. alcohol, of 0.84, 8 pts. bromine, and 1 pt. phosphorus; phosphorus and bromhydric acids are formed, and decompose the alcohol during distillation. It is separated from alco-

hol and acid by water and weak alkali, respectively. It is a colorless, very volatile liquid, of a strong ethereal odor and taste; heavier than water, under which it may be kept; soluble in alcohol.

6. *Iodide of Ethyl*. Iodohydric Ether. Form. EI ($\text{C}_2\text{H}_5\text{I}$). Prep. 1. By distilling liquid iodohydric acid, of 1.7, with alcohol, or 5 pts. iodide of phosphorus, with 2 pts. alcohol, of 0.854; the residue, treated with alcohol, yields more ether. 2. Dissolve iodine in alcohol, of 0.85, lay phosphorus in it, and keep the liquid cold; when it has become colorless, remove the phosphorus, dissolve more iodine in the liquid, and replace the phosphorus until the liquid becomes colorless; finally, distil and separate the ether by water. (*E. Kopp.*) Add 50 pts. iodine to 2—300 pts. absolute alcohol, hang a piece of phosphorus by a platinum wire in the liquid, so as not to touch the iodine. Phosphoric and iodohydric acids, and iodide of ethyl are produced. *Marchand.*

It is a colorless, ethereal liquid, of spec. grav. 1.9206, at 72°, boils at 161°, and its gas has a spec. grav. = 5.409, by experiment. It is difficultly soluble in water, readily in alcohol, slowly and slightly decomposed by alkali, nitric acid, and chlorine, rapidly by oil of vitriol. It is not inflammable, and when passed through an ignited porcelain tube is resolved into a smeary mass, resembling white wax after fusion, and with an ethereal odor.

7. *Fluoride of Ethyl*. Fluohydric Ether. EF . Pass fluohydric acid from 1 pt. fluor spar into 1 pt. absolute alcohol, distil off $\frac{1}{4}$, and mix the distillate with twice its volume of water, which separates the ether. It is colorless, smells like horseradish, very volatile, burns with a blue flame, decomposes glass, forming alcohol and silicofluoride of potassium. *Reinsch.*

8. *Cyanide of Ethyl*. Cyanhydric Ether. Form. ECy ($\text{C}_2\text{H}_5\text{NC}_2$). Prepared by distilling equal equivalents of cyanide of potassium and sulphovinate of potassa, $\text{KC}_2 + \text{EO}$, KO , $2\text{SO}_3 = \text{ECy} + 2\text{KO}$, 2SO_3 . A colorless, inflammable liquid, of a strong, garlicky odor; spec. grav. = 0.787, at 59°; boiling at 180°; scarcely soluble in water, in every proportion in alcohol and ether, and not precipitable by nitrate of silver; poisonous. *Sulphocyanide of ethyl* appears to be formed by distilling 1 pt. sulphocyanide of potassium, 2 pts. oil of vitriol, and 3 pts. alcohol, (80 pr. ct.) An oily liquid, heavier than water, with a strong odor of assafœtida.

9. *Sulphuret of Ethyl*. Sulphohydric Ether. Form. ES ($\text{C}_2\text{H}_5\text{S}$). Prepared, 1, by mixing anhydrous alcohol with muriatic acid, and dissolving in it sulphuret of iron; the sulphur ether is precipitated by water; 2, by heating in a retort sulphovinate of potassa, with protosulphuret of potassium or barium, when the ethyl and metal exchange places in their combinations; the distillate is washed with water, and rectified over chloride of calcium.

Prop. A colorless, fluent liquid, with a strong odor of assafœtida, a sweetish taste; burns with a blue flame, is not decomposed by boiling potassa ley; and makes a yellow precipitate with acetate of lead.

10. *Bisulphuret of Ethyl*. Form. ES_2 ($\text{C}_2\text{H}_5\text{S}_2$).

Distil 2 pts. sulphovinate of potassa, 3 pts. pentasulphuret of potassium, and 5 pts. water, adding more water as long as it passes over with oil; dry the distillate over chloride of calcium, and distil until the boiling point reaches 374° ; rectify repeatedly, until the distillate has a fixed boiling point of 304° . It is a colorless, oily liquid, of garlicky odor; spec. grav. = 1.00; neutral, unchangeable in air; almost insoluble in water, readily soluble in alcohol and ether; burns with a blue flame; decomposed by heated, not by cold sulphuric acid; not acted on by muriatic acid; nitric acid changes only a part of the sulphur into sulphuric acid. *Morin.*

11. *Sulphhydrate of Ethyl. Mercaptan, (Zeise).* Form. ES, HS (C_2H_5S , HS), resembling alcohol with sulphur instead of oxygen. *Prep.* By distilling equal volumes of a solution of sulphovinate of lime, of 1.28, and a solution of potassa, of 1.28, previously saturated with sulphohydric gas; or by transmitting chlorhydric ether through a similar solution of potassa. It is obtained in a well-cooled recipient, and purified by redistilling from a little oxide of mercury, and digesting with chloride of calcium.

Prop. A colorless, ethereal liquid, of a garlicky odor and taste, with a neutral reaction; spec. grav. 0.842, at 59° ; boils at 98° ; is very combustible, with a blue flame; scarcely soluble in water, freely miscible with alcohol and ether. It readily decomposes metallic oxides and salts, water being eliminated, and double sulphurets of ethyl and of metal being formed, which were termed by Zeise *mercaptides*.

Sulphuret of Ethyl and Potassium, KS, ES, obtained by the action of the metal on the sulphhydrate of ethyl, is a white, granular mass, not decomposed at 212° ; soluble in water and alcohol. The double salt of lead, PbS, ES, obtained by adding slowly an alcoholic solution of acetate of lead to an alcoholic solution of mercaptan, is yellow, crystalline. The salt of copper, CuS, ES, obtained by the action of mercaptan on the finely powdered oxide, or by mixing the potassium salt and blue vitriol, is pale yellowish white, bears considerable heat without decomposition, and burns with a bluish green color. Mercaptan shows the strongest affinity for oxide of mercury, (whence its name, *mercurium captans*), and readily forms a double salt, HgS. ES, by digesting them together; it is colorless and crystalline after fusion, almost inodorous, soft and fatty to the touch, fuses at about 187° , begins to decompose at 257° , is combustible, slightly soluble in water and alcohol, crystallizing from the last boiling hot solution in silvery lamina; unaltered by fusion under water, by boiling caustic ley, by dilute acids. The salts of silver and gold are white, that of platinum yellow; the two last withstand a heat of 342° , and more than 500° , respectively, without decomposition.

12. *Oxysulphethyl-sulphuric Acid.* Into dilute heated nitric acid drop mercaptan, letting each portion dissolve previous to adding another, evaporate in a water-bath, to remove the excess of nitric acid, saturate with carbonate of baryta, to obtain the crystallized barytic salt,

which may be decomposed by sulphuric acid, to procure the acid. Form. of the acid, HO, $SO_3 + C_2H_5SO$; in its salts, the HO is replaced by metallic oxide. *Löwig.*

The salts are all soluble in water, and contain a different number of equivs. of crystal-water. Distil mercaptan with dilute nitric acid, and separate the oil which sinks under the distillate. It is composed of $C_2H_5S_2O_2$, which may be sulphurous acid and sulphuret of ethyl, or bisulphuret of ethyl and oxysulphethyl-sulphuric acid. When this body is distilled with potassa, bisulphuret of ethyl passes over, and the potassa is united with an acid of the composition $C_2H_5S_2O_7$, with 2 KO, which may be in the salt $2(KO, SO_3) + C_2H_5S_2 + HO$. *Löwig and Weidmann.*

13. The *Telluret* and *Seleniuret* of Ethyl are obtained, like the sulphuret, from the telluret and seleniuret of potassium or sodium. The former is yellowish red, similar to bromine, with a disagreeable, garlicky odor, boils below 212° ; burns with a white flame, and with a bluish edge, giving off white fumes of tellurous acid.

14. *Sulphocarbonate of Oxide of Ethyl. Xanthelin (Zeise).* Form. EO, $CS_2 = C_2H_5S_2O$. Finely powdered sulphocarbonate of ether and potassa, is mixed to a paste with alcohol, and iodine added portionwise as long as the mixture remains colorless. The liquid is filtered and distilled; the liquid is poured off from precipitated iodide of potassium and sulphur, and the distillation continued at a gentle warmth until a pale yellow liquid of peculiar odor remains. The residue is shaken several times with water, and the oil which separates is rectified over chloride of calcium. It is an oily liquid, of a strong disagreeable odor, and burning taste; spec. grav. 1.0703, at 64.4° ; boils between 410 and 419° ; insoluble in water, readily in alcohol and ether; tincture of potassa separates it in 16 to 24 hours into carbonate of potassa, which precipitates, and mercaptan, which dissolves. *Zeise.*

15. *Sulphocarbonate of Oxide of Ethyl and Water.* EO, $CS_2 + HO, CS_2$, and is obtained by dissolving 1 pt. fused potassa in 12 pts. alcohol, of 0.8, or in 6 pts. absolute alcohol, and adding bisulphuret of carbon until the liquid has no longer an alkaline reaction, whereby the salt of potassa is formed, which is separated in crystals by cooling to 32° ; and by precipitating the excess of sulphuret of carbon in the mother liquor by water, decanting the clear liquid, and evaporating carefully in vacuo, or over oil of vitriol, more of the salt is obtained. Oil of vitriol or muriatic acid, previously diluted with 4 or 5 vols. water, is poured on the salt in a tall glass cylinder, and when a milky liquid forms, it is mixed with 4 or 5 vols. water slowly, and without stirring the deposit; 50 or 60 vols. water are then added, and the bisulphocarbonate collected at the bottom of the vessel is repeatedly and carefully washed with water. *Zeise.*

A better mode of preparing the potassa salt is to saturate absolute alcohol with fused potassa, and add an excess of bisulphuret of carbon; the whole liquid congeals to a mass

of fine crystals, and is strongly pressed out, washed with ether, and dried over oil of vitriol. *Sacc.*

Prop. A colorless, oily liquid, heavier than water, with a strong odor, and a taste at first pungent and acid, then bitter and astringent; very inflammable; heated to 75° , it boils and distills over sulphuret of carbon, then the same with alcohol, lastly, alcohol; when water is present, the former distills off alone; decomposes in the air; expels carbonic acid from alkalies and alkaline earths, with which it unites. It forms a peculiar class of salts, in which the sulphuret of carbon is united with oxidized bases; those of the alkalies and alkaline earths are soluble in water and alcohol, most others insoluble; they are combustible, decomposed by distillation, yielding, among other products, mercaptan, and a peculiar oil of strong odor and taste, termed by Zeise Xanthogen oil.

The salts of potassa and soda, $\text{KO}(\text{NaO})$, $\text{CS}_2 + \text{EO}$, CS_2 , are colorless and crystallizable, that of ammonia obtained in a dry state with difficulty. The barytic salt is obtained by agitating anhydrous baryta with a solution of sulphuret of carbon in absolute alcohol, and evaporating in vacuo; by the addition of a little water to the tough mass it congeals to a mass of crystals, and is dissolved by a little more water, yielding crystals on evaporation, with 2 eq. water; the lime-salt dries to a gummy mass. The metallic salts are obtained by double decomposition with the alkaline salts. The salts of zinc and lead, and oxide of mercury, are white and crystalline; that of copper is yellow, and exhibits the greatest resistance to decomposition; those of suboxide of mercury, of oxides of silver, bismuth, antimony, and tin, are yellow precipitates.

16. *Sulphocarbonate of Ethyl.* Form. ES , CS_2 . Dissolve potassa in alcohol, of 80 pr. ct., divide it in two parts, saturate one with sulphuretted hydrogen, and mix them together; it forms a solution of sulphuret of potassium, KS , in alcohol. Pass the vapor of chloride of ethyl into this solution, let it stand several days, when chloride of potassium separates; pass the chloride again into the liquid, and repeat until all the potassium salt is supposed to be decomposed; on adding water, an oily body separates, from which sulphuret of carbon is separated by repeatedly shaking it with a cold, aqueous solution of sulphuret of potassium. Heat acts decomposingly.

It is a yellow, oily liquid, of a garlicky odor, and an agreeable, sweetish, aromatic taste; boils at 320° ; burns with a blue flame.

OXY-SALTS OF ETHYL-OXIDE.

As ether does not directly unite with acids, its salts are formed by the action of acids on alcohol, whereby acid salts are formed: thus a double sulphate of ether and water is formed by the action of oil of vitriol on alcohol, which, from its forming salts with other bases, is termed sulphovinic acid. In like manner, we have the arseniovinic, phosphovinic, &c., acids. They all have little stability. When these acids or acid salts unite with a base, the latter replaces the equivalent of water, form-

ing a double sulphate of ether, and of the base, which is neutral.

The simple neutral salts are partly derived from the acid salts. They differ from inorganic salts, since neither the acid nor ether can be replaced by double decomposition. They are decomposed by alkaline hydrates, with the assistance of heat, their acid uniting with the alkali, and their ether with the water of the alkali, to form alcohol. Some of them are only partially decomposed by alkali and other oxides, forming double salts.

1. *Sulphate of Oxide of Ethyl and Water.* a. Syn. Sulphovinic Acid, Sulphethylic Acid, Ethersulphuric Acid. Form. EO , $\text{SO}_3 + \text{HO}$, SO_3 . *Prep.* 1. By passing vapor of ether through oil of vitriol as long as absorption ensues. 2. Treat alcohol with oil of vitriol, as directed under "Theory of the Ether Process," dilute with water, add carbonate of baryta or lead, which separates as sulphate, and after filtration evaporate the filtrate to expel alcohol. Decompose the soluble salts of baryta exactly, by sulphuric acid, or that of lead by sulphuretted hydrogen, and evaporate in vacuo over oil of vitriol. 3. Heat gently sulphate of ethyl and etherole (heavy oil of wine) with 4 pts. water; etherole rises to the surface, and the sulphovinic acid is dissolved in the water.

Prop. It cannot be obtained very concentrated; Vogel reduced it to 1.319, when it was oily and had a caustic acid taste; at a boiling heat it is so decomposed that water unites the sulphuric acid, and with ether to form alcohol. The salts of sulphovinic acid are soluble in water and spirit of wine; their sulphuric acid is not detected by the ordinary reagents; they are not decomposed by chlorine-gas, nor the alkaline salts, when boiled with excess of caustic alkali.

Sulphovinate of Potassa, EO , $\text{SO}_3 + \text{KO}$, SO_3 , crystallizes readily in large, transparent tabular crystals, by the spontaneous evaporation of a concentrated solution; they are anhydrous, permanent in air, with a sweetish saline taste, very soluble in water, insoluble in ether and absolute alcohol, infusible, begins to decompose at 212° . The soda salt, $\text{EO SO}_3 + \text{NaO}$, $\text{SO}_3 + 2 \text{HO}$, forms transparent tables, efflorescent in dry, deliquescent in moist air, soluble in water and alcohol, insoluble in ether, fusible at 187° , decomposing above 212° . The ammonia salt is soluble in water, alcohol, and ether, fusible at 144° , decomposing at 226° , evolving alcohol and oil of wine. Marchand obtained a crystallized compound of 1 eq. of this salt with 2 eq. of the potassa salt, which, when heated to 248° , yields, among other products, prussic acid. The salt of lithia is similar to that of soda in composition and properties.

The barytic salt, with 2 eq. water, forms transparent rhombic prisms, permanent in air, soluble in 0.92 pt. water, at $62\frac{1}{2}^{\circ}$, slightly in boiling alcohol. The salt of strontia is similar to the preceding, but is anhydrous. The lime salt, EO , $\text{SO}_3 + \text{CaO}$, $\text{SO}_3 + 2 \text{HO}$ separates by spontaneous evaporation of a syrupy solution in 4-sided tables, soluble in 1 pt. water, at 46° , in 0.635 pt., at 86° , and in every

proportion at 212° , heated to 230° , it at first gives off ether; it contains 17.35 pr. ct. lime, and 22.82 pr. ct. ether. The salts of *magnesia* contain 4 eq. water, crystallize in quadratic plates, soluble in water, not in alcohol or ether.

The *aluminous* salt, $3(\text{EO}, \text{SO}_3) + \text{Al}_2\text{O}_3$, $3 \text{SO}_3 + \text{mHO}$, forms an uncrystallizable, gummy mass. The salt of *manganese*, with 4 HO, forms rose-red plates, very permanent in air, soluble in water and alcohol, not in ether. The salt of *protoxide of iron*, obtained by dissolving iron in sulphovinic acid, forms greenish 4-sided prisms; that of *peroxide* forms yellow plates with some difficulty. The salt of *cobalt* forms large, dark-red crystals, that of *nickel* is green and granular, those of *zinc* and *cadmium* colorless, soluble in water and alcohol, and all contain 2 HO. The neutral salt of *lead*, with 2 HO, forms large, clear plates, soluble in water and alcohol, with an acid reaction, and yields the largest amount of oil of wine; the basic salt, $\text{EO}, \text{SO}_3 + \text{PbO}, \text{SO}_3 + \text{PbO}$, is neutral, evaporates to an uncrystallized mass, and is more fixed than the neutral compound. The *copper* salt, with 4 HO, forms large blue 8-sided plates, permanent in air, soluble in water and alcohol. The salt of *silver*, with 2 HO, forms small crystalline scales; that of *mercury* is a yellowish, deliquescent mass.

b. Modified Sulphovinic Acid. Add 2 pts. oil of vitriol, in small portions, to 1 pt. alcohol, of 0.83, so that the temperature does not rise above 32° for 12 hours, add ice-water, saturate with carbonate of lime, filter, and evaporate in vacuo. This sulphovinate of lime, of the same composition as the ordinary salt, differs in its properties, but passes into the latter by a gentle heat. The salt of potassa, formed by carbonate of potassa and the above, at a little above 32° , crystallizes with 1 eq. water. The soda salt contains 3 eq. crystal-water. The salts of lead and baryta, obtained by direct saturation of the acid with their carbonates, contain each 2 eq. water. All these salts are more fixed in their dry state than the ordinary sulphovinates, and are much more soluble.

2. *Phosphate of Water and Ether.* Syn. Phosphovinic, Phosphethylic, Ether-phosphoric Acid. Form. $\text{EO} + 2 \text{HO}, \text{PO}_5$. *Prep.* Alcohol, of 95 pr. ct., is mixed with a syrupy solution of phosphoric acid (of greater spec. grav. than 1.2), heated for some minutes to 176° , suffered to stand for 24 hours, diluted with 7 to 8 vols. of water, saturated with carbonate of baryta, boiled to separate alcohol, cooled to 158° , and filtered. The solution deposits the salt of baryta in crystals, which are dissolved in water, exactly decomposed by sulphuric acid (for 300 pts. of the salt, 76 pts. of acid), filtered, and the filtrate evaporated by heat, and then in vacuo to a syrupy consistence. A similarly made salt of lead is decomposed by sulphuretted hydrogen.

Prop. It is a very acid liquid, miscible in water, alcohol, and ether, is much less easily decomposed by heat than sulphovinic acid, to which it is not analogous, for in its neutral salts the 2 eq., HO, are replaced by 2 eq. metallic oxide, so that the ether appears not to

perform the part of base. The ether-phosphates are conveniently prepared by double decomposition of the barytic salt with soluble sulphates, or by saturating the acid with carbonates. Ether-phosphates of potassa and soda, $\text{EO} + 2 \text{KO}$ (2NaO), PO_5 , are very soluble, and difficult to crystallize. The salt of baryta, $\text{EO} + 2 \text{BaO}, \text{PO}_5 + 12 \text{HO} = 30\frac{1}{2}$ pr. ct. water, crystallizes in hexagonal plates, insoluble in alcohol and ether, 100 pts. water dissolve 3.4 pts., at 32° , 2.8 pts., at 212° , and 9.36 pts., at 104° , which is its point of greatest solubility; it bears almost a red heat without decomposition. The salt of strontia is similar to the preceding; that of lime is almost insoluble; that of lead is the most insoluble, and contains no crystal-water; the salt of silver resembles that of lime. *Pelouze.*

3. *Arseniate of Water and Ether.* Ether-arsenic, Arseniovinic Acid. Form. $2 \text{EO} + \text{HO}, \text{AsO}_5$. In the barytic salt the HO is replaced by 1 eq. of a metallic oxide, (*d'Arce*); but the analogy of phosphoric and arsenic acids would lead to a different formula.

4. *Nitrate of Oxide of Ethyl.* Nitrous Ether. EO, NO_3 . *Prep.* The action of nitric acid on alcohol is violent, and may even be explosive, carbonic acid, water, aldehyde, and other products being formed, while the nitric acid, reduced to nitrous, combines with ether. 1. Distil 3 pts. strong alcohol with 2 pts. nitric acid, of 1.3, applying, occasionally, a gentle heat, and surrounding the receiver with ice. 2. Distil 16 pts. alcohol, of 0.83, with 5 pts. sulphuric acid, of 1.85, and 8 pts. fused and coarsely powdered saltpeter; receive 12 pts. of the distillate, and rectify it. (*Bucholz.*) 3. Pour 9 pts. alcohol, of 0.83, into a cylindric bottle; through a funnel-tube with a fine opening passing to the bottom, pour 4 pts. water, and then 8 pts. strongest nitric acid; placed in a temperature of 59° , the three layers gradually unite to form nitrous ether. Carbonic acid first passes over alone, then mingled with nitric oxide, and to catch the ether which these gasses carry off, pass through the cork of the bottle a tube which is twice bent, and passes beneath alcohol in another bottle. This alcohol can be employed for another operation. The ether is finished in 2 or 3 days, and is drawn off from the acid liquid. (*Black.*) 4. Heat a large retort in a water-bath a mixture of 1 pt. starch and 10 pts. nitric acid, of 1.3, and pass the nitrous gas produced through 2 pts. alcohol, of 85 pr. ct., and 1 pt. water; the ether is conducted from the latter mixture, through a condenser, into a well-cooled recipient. 5. Dissolve 11 pts. crystallized nitrate of ammonia in a mixture of 9 pts. alcohol, and 8 pts. oil of vitriol, and distil. The distillation goes on quietly, and may be easily conducted on a large scale. *Pedroni.*

To purify nitrous ether, it is shaken with an equal volume of water, containing a little more potassa than will saturate the free acid, drawn off from the aqueous solution and rectified over a little chloride of calcium and calcined magnesia.

Prop. A pale-yellow liquid, with an ethereal odor, resembling that of apples; with a sweetish, biting taste; spec. grav. 0.886, at 39° ,

(*Dumas and Boullay*), 0.947, at 59°; it boils at 61.5° (69.8°, *Thénard*); it is very inflammable, burning with a clear, white flame; it is converted by an alcoholic solution of potassa into saltpeter and alcohol; it gradually suffers spontaneous decomposition, becoming acid; its solution in water (1 pt. in 48 pts.), becomes acid in a few days, and then contains nitric and saccharic acids; it mixes freely with alcohol, which solution is employed in medicine, under the name of sweet spirits of nitre.

Sweet Spirits of Nitre. Mix 4 pts. alcohol, of 0.833, with 1 pt. fuming nitric acid, distil off 3 pts., and rectify the distillate over calcined magnesia or neutral tartrate of potassa. Spec. grav. = 0.85. (*Swed. Pharm.*) Distil 2 pts. powdered saltpeter, 2 pts. oil of vitriol, diluted with water, to a spec. grav. 1.63, and 10 pts. alcohol, of 95 pr. ct.; shake the distillate with a little slacked lime, decant, and rectify over dried nitrate of lime, rejecting the first acid portion. Spec. grav. = 0.81. (*Duflos.*) Sweet spirits of nitre is much less alterable than nitrous ether, and may be kept for a long time in a well-closed vial, provided it be perfectly dry.

5. *Nitrate of Oxide of Ethyl.* Nitric Ether. Form. EO, NO_6 . Mix equal weights of nitric acid, of 1.401, and alcohol, of 0.835; to 3 or 4 ounces of this mixture in a retort, add 15 to 30 grains of nitrate of urea, and distil off $\frac{2}{3}$ ths at a gentle warmth; it is freed from alcohol, acid, and water in the usual way. Nitric acid tends to pass into nitrous acid by its action with alcohol, and to form nitrous ether, but urea and nitrous acid mutually and readily decompose, so that in the above mixture, the nitrous acid generated, acts on the urea, while the nitric unites with ether. It is a colorless liquid, of an agreeable odor, different from that of the nitrite, of a sweetish, then bitter taste; spec. grav. 1.112; boils at 185°; burns with a white flame, often with explosion; insoluble in water, soluble in alcohol; forms saltpeter with an alcoholic, not with an aqueous solution of alcohol. *Millon.*

6. *Perchlorate of Oxide of Ethyl.* Perchloric Ether. Form. EO, ClO_7 . Mix intimately in a mortar 70 to 90 grains of anhydrous sulphovinate of potassa with an equal weight of dry perchlorate of baryta, introduce the mixture into a small retort, and connect the latter with a tube, closed at one end, as a recipient, containing a little anhydrous alcohol, and cooled by ice. The ether begins to evolve when the temperature of the oil-bath is above 212°, and the heat is gradually increased nearly to 338°, which should not be exceeded. The alcoholic solution not being explosive, the ether is precipitated from it by water and filtered. It is a colorless, transparent liquid, of a peculiar, agreeable odor, with a sweetish, then pungent taste, heavier than, and insoluble in, water, soluble in alcohol, and when not too concentrated, this solution burns without explosion; it neither boils nor explodes in boiling water; by precipitation with water from its alcoholic solution, it is partially decomposed; a tincture of potassa immediately separates perchlorate of potassa. It is one of the most dangerous substances to handle, exploding violently by flame, spark, friction,

stroke, and often without apparent cause. *Clark Hare and M. H. Boyé.*

7. *Carbonate of Oxide of Ethyl.* Carbonic Ether. Form. EO, CO_2 . Prepared by warming potassium or sodium under pure oxalic ether in a retort, when carbonic oxide is chiefly evolved, and a dark-red mass remains; when this is mixed with water, the ether rising to the top is separated, dried, by contact with chloride of calcium, decanted, heated, to drive off alcohol and ether, and rectified over sodium, to free it from oxalic ether.

Prop. A thin, colorless liquid, of an agreeable aromatic odor, and a sharp, aromatic taste; spec. grav. 0.975, at 66°; very soluble in alcohol and ether, insoluble in water; boils at 258°; not very inflammable, burning with a blue flame; its alcoholic solution, warmed with caustic soda, produces carbonate of soda and alcohol. *Ettling.*

Carbonate of Ether and Potassa. Form. $\text{KO}, \text{CO}_2 + \text{EO}, \text{CO}_2$. Hydrate of potassa, previously fused at a red heat, is dissolved in absolute alcohol, and carbonic acid passed into the well-cooled solution until it congeals; an equal volume of anhydrous ether is added, filtered, and the precipitate washed with anhydrous ether. Absolute alcohol is then poured through the filter, which leaves carbonate and bicarbonate of potassa, and dissolves the ether-carbonate, the filtrate dropped into anhydrous ether, and the precipitated salt rapidly dried in vacuo. It is anhydrous, pearly, and instantly changed by water into alcohol and bicarbonate of potassa. *Dumas and Peligot.*

Chlorocarbonic Ether. Chloroxycarbonic Ether, Carbonic Ether, and Chloride of Carbonic Oxide. Form. $\text{EO}, \text{CO}_2 + \text{CO}, \text{Cl}$. Formed when alcohol absorbs chlorocarbonic acid (see under CARBON), whereby it separates into two layers, the upper aqueous and acid, the lower containing this ether; it is rectified over chloride of calcium and oxide of lead, to remove water and muriatic acid. It is a fluent, colorless liquid, of neutral reaction, with a strong odor, attacking the eyes; spec. grav. 1.139, at 59°; boils at 201°; is inflammable, burning with a green color; is insoluble in cold, partially decomposed by warm water.

Urethan. Carbonic Ether and Amide of Carbonic Oxide. Form. $\text{C}_6\text{H}_7\text{NO}_4$, or $\text{EO}, \text{CO}_2 + \text{CO}, \text{NH}_2$. Dissolve chlorocarbonic ether in ammonia, evaporate to dryness in vacuo, and distil in an oil-bath. Urethan passes over as a liquid, but congeals in the recipient to a colorless, sperm-like mass, fusible below 212°, and may be distilled, when dry, at 226.4°; soluble in cold or warm water, in alcohol; the latter solution does not precipitate nitrate of silver, and yields fine crystals by spontaneous evaporation. *Dumas.*

8. *Borate of Oxide of Ethyl.* Borovinic Acid. $\text{EO}, 2 \text{BO}_3$. Mix in a retort, provided with a thermometer, equal pts. of finely powdered, anhydrous boracic acid and absolute alcohol, and distil off alcohol until the temperature is 230°; treat the mass, when cold, with anhydrous ether, which dissolves the boracic ether, and distil the solution until the temperature of 392° is attained. The retort

contains the fused ether, a colorless, transparent solid, of ethereal odor and a burning taste, moderately hard, may be drawn into threads between 104° and 122° , is soluble in alcohol and ether, fumes in the air, is converted by water into alcohol and boracic acid; at 572° it separates into pure olefiant gas, and hydrate of boracic acid. *Ebelmen.*

9. *Silicic Ethers.* Absolute alcohol is added portionwise to perchloride of silicon, and when the volume of the former slightly exceeds that of the latter, there is an elevation of temperature; it is now distilled, its boiling point being between 310° and 338° , when the greater part passes over and is caught separately; the distillation is continued until the boiling nearly reaches 600° , and this distillate contains another ether. The former is rectified until it has a constant boiling point of $322\frac{1}{2}^{\circ}$ to $324\frac{1}{2}^{\circ}$, when the ether passes over, as a colorless liquid, of a penetrating odor and peppery taste; spec. grav. 0.932; miscible with alcohol and ether, insoluble in water, which slowly decomposes it; its alcoholic solution, mixed with potassa, forms silicate of potassa; dropped upon ignited platinum, it burns with a white flame; form. $3\text{EO}, \text{SiO}_3$. When the second distillate is also rectified, and that portion caught when the boiling point has reached 574° , another ether is obtained, differing from the preceding, in its having but little odor, a bitter taste, a spec. grav. = 1.035, and a formula $3\text{EO}, 2\text{SiO}_3$; otherwise, it resembles the former. *Ebelmen.*

10. *Cyanite of Oxide of Ethyl and Water.* Cyanvinic Acid. Form. $\text{EO}, \text{CyO} + \text{HO}, \text{CyO}$. Formed by distilling dry cyanuric acid, and receiving it in absolute alcohol; the distillate, hydrated cyanic acid, changes again into cyanuric acid, one part of which unites with the ether, and another with the water of the alcohol, and the two unite, forming a cyanite of ether and of water, which deposits in a solid form in the recipient. The alcohol is poured off, and the cyanvinic acid dried; by solution with boiling in a mixture of alcohol and ether, by gradual cooling, and spontaneous evaporation, it is obtained in colorless pearly crystals. It is soluble in alcohol and ether, almost insoluble in cold water, but so very soluble in hot that the saturated solution congeals on cooling to a mass of fine, silky crystals; soluble without decomposition in sulphuric and nitric acids, with decomposition in hot alkali; its vapor burns with a purple flame.

ORGANIC ETHERS.

There is generally more difficulty in preparing compounds of ether with organic acids, in consequence of the greater facility with which these acids are decomposed. The principle involved is the same, the catalysis of alcohol, whether by a strong mineral acid in the presence of an organic acid, or by the organic acid itself. There are several methods by which this is accomplished. One method is to set the acid free from a state of combination in the presence of alcohol, thus in Wöhler's process for butyric ether, butter is saponified with strong potassa ley, dissolved with warmth

in a small quantity of strong alcohol, treated with a mixture of sulphuric acid and alcohol, until it has a strong acid reaction, and distilled as long as the distillate has the odor of ripe apples. By rectification and treatment with chloride of calcium it is obtained pure. In this case, the sulphuric acid both sets the butyric acid free, and catalyzes the alcohol. In a similar manner, by decomposition of salts of organic acids by sulphuric acid, many ethers may be formed, as oxalic, acetic, formic. See BUTYRIC ACID.

Another method is simply to catalyze alcohol by sulphuric or muriatic acid, in the presence of the organic acid. Thus Cahours prepares spirylic ether, by distilling 3 pts. crystallized spirylic acid (salicylic acid) with 4 pts. absolute alcohol, and 2 pts. oil of vitriol, stopping the distillation when sulphurous acid is evolved. Repeated rectification with water containing a little ammonia, to separate acid, and with chloride of calcium to dry it, is requisite for purification. In like manner, by the presence of sulphuric acid, stearic, oleic, citric, camphoric, suberic, &c., ethers are formed.

Muriatic acid is similarly employed; thus by distilling $\frac{2}{3}$ of a mixture of 4 pts. alcohol, of 0.83, 2 pts. benzoic acid, and 1 pt. concentrated muriatic acid, a small quantity of benzoic ether passes over, but the greater part remains, and by repeated rectification of the distillate over the residue, nearly all the benzoic acid is converted into ether, which is farther purified by washing with water, and distilling with oxide of lead. In like manner, succinic ether is obtained by repeated distillation of 2 pts. succinic acid, 4 pts. alcohol, and 1 pt. strong muriatic acid. The muriatic also presents this convenience, that it may be passed into an alcoholic solution of an organic acid; thus cocostearic ether is prepared, by passing muriatic gas into a saturated solution of cocostearic acid in alcohol, adding water, and boiling the solid ether with a solution of carbonate of soda. This method is especially applicable to ethers of the fat acids, whether dissolved or partly suspended in alcohol.

By repeated distillation of very concentrated acetic or formic acid and alcohol, acetic or formic ether is formed, although the addition of sulphuric acid greatly facilitates the formation of the ether.

M. de Claubry has shown, that the more fixed organic acids may catalyze alcohol alone, by being heated nearly to their point of decomposition, and then dropping strong alcohol upon them, such as the oxalic, benzoic and succinic. Although this fact is interesting, the process must yield in convenience, and speed to the other methods of catalyzing alcohol by a stronger mineral acid in presence of the organic acid.

For a description of the organic ethers, see the organic acids, such as ACETIC, CITRIC, MARGARIC, &c.

OTHER PRODUCTS OF THE CATALYSIS OF ALCOHOL.

1. *Distillation with Oil of Vitriol.* a *Oil of Wine.* An oily body, long since known, and

obtained in preparing olefiant gas from alcohol and oil of vitriol, by passing the gas into a well-cooled vessel in which a solution of oil of wine in ether condenses. It is an oily body; spec. grav. 0.914; insoluble in water, slightly in alcohol, readily in ether. Analyses by Dumas, and Boullay, and Liebig, give the formula C_8H_8 . Masson observed that the compound of chloride of zinc and alcohol gave ether and water, when heated to 284° , and between 320° and 393° , two liquid hydrocarbons, one boiling at 212° , with the formula C_8H_8 , and the other boiling at 572° , with the formula C_8H_8 ; the sum of which, $C_{16}H_{16}$, represents the composition of olefiant gas.

b. *Sulphate of Oxide of Ethyl and of Etherole*. Sweet or Heavy Oil of Wine. Form. C_4H_4O , $SO_3 + C_4H_4$, SO_3 , or $2(C_4H_4), SO_3 + HO$. Obtained by distilling equal pts. of dry sulphovinate of lime and caustic lime, and freeing the distillate from alcohol in vacuo over oil of vitriol. It is a colorless, oily body, of a penetrating, aromatic odor and taste; spec. grav. 1.33; boils at 536° ; is decomposed by boiling water, acids, and alkali, into sulphovinic acid and etherole.

c. *Etherole*. Syn. Etherin, Ethène, Light Oil of Wine. Form. C_4H_4 . Obtained from the preceding by alkali, &c.; is exposed for some days to a low degree of cold, whereby crystals of etherin separate. Etherole is a yellowish oil, of a peculiar, aromatic odor; spec. grav. 0.917; boils at 536° , and solidifies at -31° ; soluble in alcohol and ether.

d. *Etherin*. Form. C_4H_4 . The solid, separating from crude etherole, forms long, hard, brittle, colorless, and lustrous prisms, tasteless, resembling etherole in odor, when heated; spec. grav. 0.98; fusing at 230° , boiling at 500° , distilling over unaltered; soluble in alcohol and ether.

2. Action of Anhydrous Sulphuric Acid.

a. *Carbyl-sulphate*. Form. CH, SO_3 . Pass the vapor of dry sulphuric acid into a flask, into which introduce a tube containing absolute alcohol, and close the flask; when the mutual action has ceased, place the tube in another vessel of the acid, and thus, successively, until the alcohol is changed to a crystalline mass. Put this mass upon a tile of porcelain biscuit, and the latter in vacuo over oil of vitriol, until the mass ceases to fume in the air. The crystals may be fused with care, and congeal again to a crystalline mass. *Magnus*.

b. *Ethionic Acid*. Formed by the action of water on carbyl-sulphate; thus, $4(CH, SO_3) + 3HO = C_4H_4O, 2SO_3 + 2(HO, SO_3)$; which is ethionic acid, whose salts are formed by the substitution of 2 eq. metallic oxide, for the 2 eq. water. The salts are most conveniently formed from the barytic salt, and other soluble sulphates. The former is obtained by saturating the acid with carbonate of baryta, concentrating the solution much below 212° , and when the salt begins to deposit, adding absolute alcohol, until the clear liquor has a spec. grav. = 0.9, which prevents the precipitation of isethionate of baryta. The precipitate is washed with alcohol, of 65 pr. ct., redissolved in a little water, and reprecipitated with alcohol, in order to get it pure; and

finally left to spontaneous evaporation, to free it from alcohol. It is soluble in 10 pts. water, at 68° , and, by heating, is readily converted into sulphate, and is ethionate of baryta; a similar decomposition commences even with the dry salt, at 212° . The salt of potassa is readily crystallizable, and is anhydrous. The soda salt crystallizes with 1 eq. water. The salts of lime and lead crystallize, and resemble ethionate of baryta. The copper salt crystallizes with difficulty. *Magnus*.

By the action of anhydrous sulphuric acid on olefiant gas, a crystalline compound is obtained, with the formula C_2H_2, SO_3 (*Regnault*); it coincides in its properties with ethionic acid, and has 1 eq. more of sulphuric acid, or 1 eq. less of CH than given in the formula. *Magnus*.

c. *Isethionic Acid*. Ethionic acid, and its salts, are readily converted, by boiling, into sulphuric and isethionic acids. Ether, at 32° , is saturated with anhydrous sulphuric acid, the syrupy mass is mixed with an equal volume of ether, and then, with 4 vols. of water, whereby ether and oil of wine separate and are removed; the liquid is boiled several hours, until every trace of sulphurous acid and alcohol are removed, fresh water being added to replace the evaporation, then saturated with carbonate of baryta, filtered and evaporated; during this and the cooling, a crystalline body separates. The liquid is mixed with an equal vol. alcohol, which removes more of the same salt, filtered and evaporated to a syrupy consistence, from which pure isethionate of baryta crystallizes. (*Liebig*.) The salt of baryta boiled, and exactly decomposed by sulphuric acid, forms a solution of isethionic acid, which may be evaporated to a syrupy consistence. (*Magnus*.) Both isethionic and ethionic acids, and the isethionates, are isomeric with sulphovinic acid and its salts, respectively, save in the amount of crystal-water. The isethionic is a strong acid, evolving muriatic and acetic acids from common salt, and an acetate, without forming muriatic or acetic ether; it forms neutral, soluble salts, of which those of the alkalies and alkaline earths bear at least 600° , without decomposition.

Methionic Acid. This acid is in the barytic salt insoluble in alcohol, obtained in preparing the isethionic acid by Liebig's method. The barytic salt has the composition $BaO, SO_3 + CH_3SO_3$, but we know not yet what the rational formula of the last body should be. *Liebig*.

Althionic Acid is, according to Magnus, a mixture of ethionic and isethionic acids.

Thiomelanic Acid. Mix 8 to 10 pts. oil of vitriol with 1 pt. absolute alcohol, heat gradually, and not beyond 356° , until it forms a lumpy mass, mix with water to a paste, dilute with more water, pour off the acid liquid, add and pour off boiling water until chloride of barium shows the absence of sulphuric acid, and dry the mass. It is black and shining, like coal, loses much water before 302° , at which it has the composition, $C_{80}H_{24}S_3O_{20}$, bears 338° without decomposition. (*Erdmann*.) Probable formula $2SO_3 + C_{80}H_{24}SO_{14}$, and the conjugate may be $C_{80}H_{24}O_{12} + SO_2$. *Berzelius*.

ETHER AS LETHÆON. The following remarks on letheon were furnished, by request, by E. R. Mayer, M. D., Philadelphia.

Lethæon is the name proposed by the patentee for sulphuric ether, when used for rendering the inhaler insensible to the pain of surgical operations, or for other important indications in the treatment of disease. Too little time has elapsed since the first practical employment of this agent, to justify a very decided opinion upon its merits; and it may be expected, that until data enough have been collected for exact statistical information, scientific men will be divided, as at present, into warm supporters, and violent denouncers of its use. If it should only prove the means of alleviating necessary pain, and warding off the shock which this always produces on a sensitive, nervous system, it will perhaps be as great a blessing to mankind as ingenuity has ever developed.

The intoxicating powers which ether and nitrous oxide gas possess, when inhaled, seem to have been known from, or before, the time of Dr. Beddoes; and the former was early used by a few persons as a therapeutic agent for various affections of the bronchia and the lungs. Sir Humphrey Davy seems to have had a faint foreshadowing of its future use. Mr. Wells, of Hartford, Connecticut, and others, claim the honor of having first employed nitrous oxide as an anodyne; but to Drs. Morton and Jackson, of Boston, is certainly due the credit of first promulgating the discovery as now known. The respective claims of these gentlemen have not been satisfactorily settled, but the former, an energetic young dentist, undoubtedly first administered the agent, and took the most active part in investigating and making it known.

The ether used for inhalation, in order to produce satisfactory results, should be perfectly pure and anhydrous, and particular care should be taken that it do not change the color of litmus paper.

The administration of the vapor is effected in various ways. Most American surgeons prefer a sponge, saturated with the fluid, and held to the nose and mouth. This simple mode, though more wasteful, is the most convenient, perhaps the best, as it allows the due intermixture of atmospheric air with the vapour. Various expensive and complicated apparatuses have been devised for the same purpose, but most of them consist of a vessel like a retort-receiver, containing a little ether, with one orifice to admit the air, and another for a mouth-piece, which is the most important part of the apparatus. This is constructed with a nipple for the mouth, with or without a caoutchouc shield fitting accurately to the cheeks, and tied behind the neck, and containing two valves of opposite action, which allow the expiration at the side, of the air which has already passed through the lungs from the ether receptacle. To some of these instruments is added a nose-compressor.

When given as a tranquillizer, ether very seldom produces the furious intoxication which we see in those who are under the influence of nitrous oxide; and even where it does, a

persistence in its use is soon followed by insensibility. Although peculiar constitutions are differently affected, the following symptoms are usually presented. Upon first inspiring the vapor, a little irritation of the bronchia, and coughing, are produced. These soon subside, and the inspirations become short, and the expirations slow and feeble. The arms become relaxed, the eyelids tremble, and perception is lost. The head now drops on one side, the patient is perfectly insensible, and cannot be roused by the infliction of pain. In this condition the imagination is most active, and the most vivid dreams follow each other in rapid succession.

There is a strange difference between the effects of ether, when employed as above described, and those generally seen when it is taken for the purposes of amusement. We have often seen it so used; but, while entire insensibility was produced, it was, in a few cases, only preceded by violent excitement, such as the rest labored under. It is probable, that the position of the inhaler, and the preoccupation of his mind, may so impress his nervous system, as to make it susceptible of different modes of action.

It would be out of place here, to enter into a discussion of the remote physiological effects of ether; it being sufficient for our purpose to know, that it temporarily, but completely, abolishes sensibility, and the ordinary reflex actions of the medulla oblongata and spinal marrow, which are unconnected with necessary vital processes.

Many hundreds of operations have now been performed in this country and in Europe, upon patients insensible from the use of ether, and, while failures have been reported, and rumors have been rife, of the dangerous, and even fatal, results from both the inhalation of the agent, and from operations performed upon those having inhaled it, the great majority of medical men who have seen its use, warmly recommend it. There can be no doubt of the entire immunity from pain conferred by it. Whether injurious or fatal effects often follow its use, remains to be seen.

But few cases of death following operations upon etherized persons, have been as yet reported, and these have, by the advocates of the use of ether, been attributed to the direct effect of the operation alone; in other words, the shock upon the nervous system of the patient. On the other hand, one great argument in favor of its employment has been, that this shock is, in such cases, much diminished by the abolition of its chief cause—physical agony.

Lethæon has also been used in various diseases not requiring the knife. It has been effectual in dissipating, temporarily removing, or permanently relieving, the pain of neuralgia; and conflicting accounts have been given of its use in tetanus, asthma, insanity, and whooping-cough. But perhaps the most wonderful results yet known, have been derived from its administration in obstetrical practice. It has been most positively shown, that while parturient women are rendered, by it, insensible to pain, it does not in the least degree

control or diminish the contractions of the womb, or the power by which the fœtus is expelled. It has, accordingly, been used in cases of severe and instrumental delivery with perfect success, not one fatal result having yet been made public. Indeed, the opinion has been advanced, that before long it will be used for the purpose of making every natural labor a painless process. In the present state of our knowledge, however, too much caution cannot be used in its application to this branch of medical practice.

It remains to mention another mode of administering ether, which the characteristic ingenuity of a French surgeon has made known. M. Pirogoff has stated, that the anodyne effects of ether may be readily produced by causing its vapor to ascend into the rectum. If experiment should confirm the truth of his statement, and prove the safety of his process; it may be well worthy of trial in cases where diseases of the lungs, heart, or bronchia, make the inhalation dangerous.

The notoriety which this subject has of late acquired from the novel and marvellous results afforded by it, has given rise to an excited state of the public mind, which may do much harm. The same love of excitement which makes consumers of alcohol and opium, may induce rash persons first to venture upon, and then to accustom themselves to the use of ether.

Such perversion of a good mean to bad ends cannot be too strongly reprehended. The fact should be generally known, that if its use is at first fascinating, its devotee must very soon be ruined in health, and become an idiotic and degraded debauchee.

Whether the dangers flowing from the use of ether have been exaggerated or not, it is but reasonable to believe, that an agent so powerful for good may be equally so for evil; and experience in our own country has shown that—in the hands of ignorant persons—it has increased a tendency to apoplexy, congestion of the brain, and diseases of the lungs.

The inference is, that no one with a disposition to disease of the brain, the heart, the lungs, and several other organs, should use it; and that it should never be administered by persons unable to judge of the existence of such disease. A competent medical or other man, acquainted with the principles of physiology and pathology, and the practice of auscultation, should invariably see the patient previous to the inhalation of the ether, so as to be enabled, by a close examination, particularly of the heart and lungs, to decide upon the prospects of benefit or injury. By such a precaution, many risks to life and health may be prevented.

ETCHING. That species of engraving upon metal by which the delineations are first drawn upon a resinous resist-coating of the metallic surface, and then *bit* out with nitric acid. The depth of the lines are proportional to the time of action of the acid, and can be rendered very delicate by diluting it with alcohol. The process being completed, and the covering removed, the plate is ready to be printed from. Glass, similarly coated, can

also be etched upon, by substituting fluohydric gas for the nitric acid.

EUCHROITE. *Min.* Cryst. Right Rhombic, with distinct lateral cleavage. $H. = 3.75$. $G. = 3.389$. Emerald-green, with pale-green streak; vitreous; transparent, translucent; doubly refractive; rather brittle, with uneven, small conchoidal fracture.

Yields water in a tube, becoming yellowish green, pulverulent, otherwise behaving like **OLIVENITE**. Formula $4 \text{CuO}, \text{AsO}_5 + 7 \text{HO}$, or $(3 \text{CuO}, \text{AsO}_5 + 6 \text{HO}) + \text{CuO}, \text{HO}$.

It occurs at Libethen, in Hungary, in crystals of considerable size.

EUCLASE. *Min.* Prismatic Emerald. Cryst. Oblique Rhombic; cleavage perfect, parallel to base. $H. = 7.5$. $G. = 2.9 - 3.1$. Pale mountain-green, passing into blue and white; vitreous; transparent; doubly refractive; very brittle, with conchoidal fracture and white streak; electric by friction.

Chem. Relat. Swells, when strongly heated, and fuses in thin films to a white enamel, dissolves in the fluxes, and gives traces of tin with soda; insoluble in acids. The older formula is $\text{G}_2\text{O}_3, \text{SiO}_3 + 2(\text{Al}_2\text{O}_3, \text{SiO}_3)$, but by the late determinations of Awdejew for Glucina, it is $2(3 \text{GO}, \text{SiO}_3) + 2 \text{Al}_2\text{O}_3, \text{SiO}_3$.

It occurs in Peru; Villa Rica, in Brazil; at Trumbull, Connecticut.

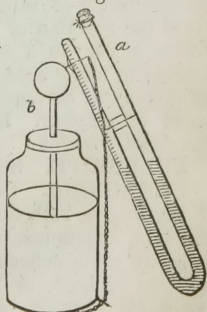
EUCLALITE. *Min.* Cryst. Hexagonal, hemiforms; the radical R combined with its lateral-edged scalenohedron, with the second obtuse R, and the terminal plane, parallel to which its cleavage is perfect. $H. = 6$. $G. = 2.9$. Brownish or rose-red; vitreous; opaque, subtranslucent; conchoidal or splintery fracture, and white streak.

Chem. Relat. Fusible to a gray-green, opaque glass; in mic. salt the silica swells up the bead; with soda it forms a difficultly fusible glass. Gelatinizes with muriatic acid, and is wholly decomposed. Form. $2(3 \text{RO}, 2 \text{SiO}_3) + \text{Zr}_2\text{O}_3, 2 \text{SiO}_3$, in which RO is lime, soda, potassa, protoxides of iron and manganese. The iron and manganese were formerly supposed to be sesquioxides. *Rammelsberg.*

Found only at Kangerdluarsuk, in West Greenland.

EUDIOMETER. *Chem.* An instrument used in determining the amount of oxygen in a given volume of atmospheric air, or other gaseous body. The eudiometer of Dr. Ure is an excellent instrument. It is formed of a straight tube, moderately stout, of about $\frac{1}{4}$ th or $\frac{3}{8}$ ths of an inch internal diameter, sealed at one end, and about 22 inches long. The closed end of this tube being softened by heat, two stout platinum wires are thrust through the glass from opposite sides of the tube, so that their extremities in the tube approach within one-tenth of an inch of each other. These are intended for the transmission of the electric spark, and are retained, as if cemented, in

Fig. 71.



EUGENESITE.

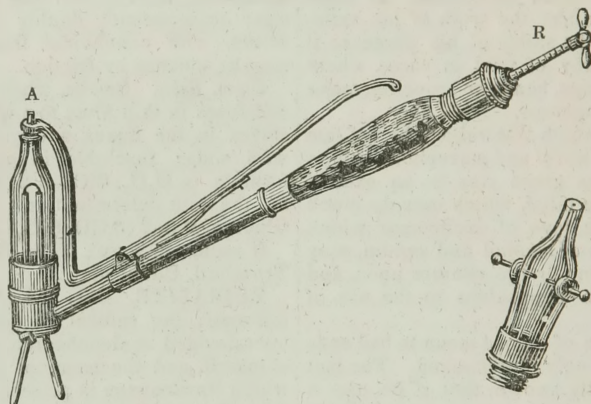
the apertures of the glass when the latter cools. One half the tube next the closed end is afterwards graduated into hundredths of a cubic inch, and the tube is bent in the middle, like a syphon, as represented by *a* in fig. 71. By a little dexterity, a portion of the gaseous mixture to be exploded is transferred to the sealed limb of the instrument, at the water or mercurial trough, and the measure noted with the liquid at the same height in both limbs. The mouth of the open limb may then be closed by a cork, which can be fixed down by soft copper wire. A chain being now hung to the one platinum wire, the other is presented to the prime conductor of an electric machine, or to the knob of a charged Leyden

EUXENITE.

phial, *b*, so as to take a spark through the mixture, which is thereby exploded. The risk of the tube being broken by the explosion, which is very considerable in the ordinary form of the eudiometer, is completely avoided in this instrument by the compression of the air retained by the cork in the open limb, this air acting as a recoil spring upon the occurrence of the explosion in the other limb. *Graham.*

Fig. 72 represents Hare's aqueous, hydro-oxygen eudiometer, for the analysis of explosive mixtures. The measurements are made by a sliding rod, *R*, and the explosions are effected by the galvanic ignition of a platinum wire.

Fig. 72.



In this instrument, the igniting wire is soldered into the summits of the two brass wires, which pass through the bottom of the socket, parallel to the axis of the glass recipient, within which they are seen. One of the wires is soldered to the socket, the other so that it has no metallic communication with the other wire, except through the filament of platinum by which they are connected above. The glass has a capillary orifice at the apex, *A*, closing by means of a spring and lever. The sliding rod, *R*, is accurately graduated to about 160 degrees.

EUGENESITE. See **PALLADIUM**.

EUKAIRITE. *Min.* Syn. Seleniuret of Silver and Copper. *Ger.* Selenkupfersilber. Massive; color between silver-white and lead-gray; metallic; soft; streak shining. Fusible, with evolution of selenic vapors, forming a gray, soft, brittle globule; in an open tube yields a red sublimate of selenium and selenic acid; gives the reaction of copper with fluxes, and yields silver on a cupel, by means of lead; soluble in nitric acid. Form. $\text{Cu}_2\text{Se} + \text{AgSe}$, analogous to Stromeyerite with selenium instead of sulphur. It occurs at Skrickerum, Smaland, Sweden.

EULEBRITE. See **RIOLITE**.

EUPHORBIA. *Chem.* The *E. esula*, and *E. cypanssias*, both contain a beautiful yellow coloring substance, which may be precipitated from an alum decoction of the plant by basic acetate of lead, or protochloride of tin. Its alcoholic tincture, by long standing, deposits a volatile, white, crystalline camphor, and the

liquid remaining upon evaporation yields a green resin, similar to **EUPHORBININ**. Riegel found in the *E. cypanssias*, both an alkaloid (?) and a new acid (? *euphorbic*), which crystallizes in acicular or verrucous groups.

EUPHORBININ. Formula $\text{C}_{14}\text{H}_{12}\text{O}$ (*Rose*). A crystallizable resin, from the *Euphorbia officinalis*, and *E. Cananensis*. When pulverized, its taste and odor are very pungent. Buchner and Herberger consider it a compound of an acid resin with a basic resin, the first of which is termed by Berzelius, *alpha* resin, and the latter, *beta* resin, or *euphorbin*. A third resin, also contained therein, is styled *gamma* resin. The acid resin is precipitated from its tincture by sugar of lead, and the beta resin from the remaining solution by water. The gamma resin is obtained from that portion of euphorbinin insoluble in water, first by cold, and then by boiling alcohol, from which last it crystallizes. Its analogy to crystallized elemi resin is very near.

Euphorbin is colorless, vitreous, and bitter, insoluble in water, ether, and the alkalies, but soluble in alcohol.

EUPION. See **WOOD**, Destructive distillation of.

EUPYRCHROITE. See **APATITE**.

EUTHOTIDE. *Geol.* Serpentine rock, with an excess of felspar and diallage.

EUXENITE. *Min.* *H.* = 7. ? *G.* = 4.6. Massive; brownish black; lustre metallic, greasy; in thin splinters reddish brown, translucent; fracture subconchoidal, with reddish brown streak. Infusible; soluble in the fluxes,

yielding yellow glasses; not attacked by acids. It contains columbic and titanac acids, yttria, lime, oxides of uranium, cerium, lanthanum, &c., and hence a formula cannot be given. It occurs at Jölster, Norway.

EUZEOLITE. See HEULANDITE.

EVAPORATION. *Chem. Tech.* An important operation in chemistry and the arts, having for its object the separation of the more volatile portions of a liquid, which are not required as in distillation. It is effected either by exposure to the air without ebullition, *evaporation*, or by the aid of sufficient heat to produce ebullition, *vaporization*. Some of the attendant circumstances varying, it is more convenient to consider the two methods separately.

1. *General Principles.* a. *Evaporation.* Most liquids evaporate at common temperatures without the appearance of ebullition, their vapor rising only from the surface of the liquid, and not from the interior, as in ebullition. Water exposed in a shallow vessel to the air, will disappear in a few days, and a solution of common salt will also dry up, leaving crystals of salt. Even many solids are subject to evaporation. Ice, far below 32°, will gradually disappear, without melting, in clear, frosty weather; camphor readily volatilizes at common temperatures without fusing, and metallic arsenic does the same by the application of heat. Evaporation takes place more rapidly in some liquids than in others, and those which have the lowest boiling points evaporate with the greatest rapidity. Thus ether evaporates more rapidly than alcohol, and the latter more rapidly than water.

It was ascertained by Dalton, that vapors and gases enter the air as into a vacuum, and Graham has more fully investigated the subject with respect to gases, under the term *DIFFUSION*. Since vapors diffuse into the air only from the surface of liquids, an extension of surface greatly facilitates evaporation. The dryness of the air exerts an important influence on rapid evaporation, especially on the diffusion of aqueous vapor. When a vapor diffuses itself through the air above the surface of a liquid, the air becomes charged, and hinders the tendency of the liquid to evaporate. Hence a current of air passed over the surface of a liquid, facilitates its evaporation, but, since time is requisite for the diffusion, the current need not be rapid.

Heat promotes evaporation, without ebullition, by its diminishing the force of cohesion between the particles of a liquid. A diminution of pressure also facilitates evaporation.

It follows, from the principles laid down, that to attain the most rapid evaporation, a liquid should be heated in a shallow vessel, while a current of dry air is passed over its surface, or a current of dry air should be forced through the liquid.

Since liquids and solids emit vapor below their boiling points, even in vacuo, it would be interesting to inquire at how low temperatures they will evaporate. Few direct experiments have been made to determine this point. The point where vapor ceases to be emitted is different for different bodies: thus

oil of vitriol seems to give off no vapor below 120°, and mercury none below 40°, whereas, water still evaporates far below its solidification, 32°.

b. *Vaporization.* Some of the circumstances attendant upon the evaporation of a liquid by boiling, are different from those just noticed. See *EBULLITION*. Since vaporization takes place from all the interior of a liquid, extent of surface has no influence in promoting it; on the contrary, it is facilitated by partially covering the containing vessel, for if aqueous vapor, at 212°, rise from a surface of moderate extent, the cooling action of the air condenses a portion, which falls back into the vessel. The smoothness of the interior surface of the vessel hinders the free escape of vapor from a liquid heated to boiling, and hence the advantage of roughness, angular points, of scraps of platinum, iron-filings, &c.

Every peculiar liquid has its definite and fixed point of temperature when ebullition takes place, pressure and other things being the same. At 30 inches of the barometer, and in a metallic vessel, water boils at 212°.

The following table comprises the boiling points of a few liquids, not all determined with accuracy, *i. e.* with reference to pressure, nature of the containing vessel, &c. The determination of the boiling point, like the fusing point of solids, is often of use, especially in organic chemistry, for ascertaining the nature and purity of a substance.

Chlorhydric ether	53°
Common ether	98°
Bisulphuret of carbon	114°
Methylic alcohol	140°
Absolute alcohol	172°
Water	212°
Glacial acetic acid	248°
Amylic alcohol	294°
Oil of terpentine	314°
Oil of lemons	343°
Oil of lavender	397°
Camphoric acid	482°
Phosphorus	554°
Oil of vitriol	620°
Mercury	662°

The temperatures given are for the pure liquids, for if they contain fixed matters in solution, their boiling points are higher. A solution of 28 pts. common salt in 100 pts. water, boils at 230°; a solution of 212 pts. dry chloride of calcium in 100 pts. water boils at 320°.

A vessel may be heated too hot to boil off water, for if a few drops of water be thrown on a metallic surface, heated much above 212°, they spring briskly over the surface, and evaporate the more slowly the hotter the surface is. This phenomenon is due to the repulsive action of heat, which more or less prevents the contact of the water and metallic surface.

The pressure of the atmosphere exerts an important influence in elevating the boiling point of a liquid. Thus, with the barometer at 29.8 inches, water boils at 212°, at 27½ inches, at 208°; variations which actually take place on the earth's surface. If the pressure

be increased the boiling point may be greatly elevated, as in Papin's digester, to 400° or more. See **EBULLITION** and **DIGESTER**. On the other hand, by greatly diminishing the pressure, or producing a partial vacuum, the boiling point of a liquid is materially lowered. This may be effected by expelling air from a tight vessel by steam, and condensing the steam, or by an air-pump. When a good vacuum is produced, water will boil at 67°, or 145° lower than its ordinary boiling point. An important application is made of this fact to boiling **SUGAR** under diminished pressure.

2. *Evaporation for Smaller Chemical Operations.* There are many peculiar circumstances occurring in chemical investigations, in which the evaporation of a liquid must be performed, where the mode of conducting it may exert an important influence on the result.

Evaporation is generally conducted in the open air by the aid of heat.

a. In analysis, it should rarely be performed by ebullition, since the spirting occasioned by the turbulence of the boiling liquid may occasion loss, but when ebullition is necessary, it may be performed in a matrass. Evaporation may be performed in capsules, filtering glasses (figs. 10 and 11, p. 169, **ANALYSIS**), or other convenient vessels, placed over a lamp, on a sand-bath, in a water-bath, &c., but to prevent dust from falling in, they should be covered by unsized paper, folded and pleated under the rim. The vapor will readily pass through, but care must be taken not to suffer the liquid to spirt upon the cover. The escape of vapor is facilitated by placing the vessel in a gentle current of air. If a heavy powder deposit during evaporation, the heat accumulating around it at the bottom is apt to generate steam suddenly, and to throw out portions of liquid. This may be obviated by heating the inclined and rather deep vessel, such as a platinum crucible, upon the lower side, and above the deposit. On evaporating to dryness, also, as in the case of gelatinizing silica, the extrication of the last portions of water from the solid matter is apt to throw out particles of the solid, which may be prevented by constantly stirring the mass towards the last until dry, or by placing the vessel in a gentle heat, in a water or sand-bath, or far above a low flame. If a substance effloresce, and travel up the sides of the evaporating vessel, its progress may be stopped by heating the sides more than the bottom, whereby a deposit of the dry substance checks the rise of the rest.

b. *Spontaneous evaporation in the air* is employed where a higher temperature might injure the substance contained in the liquid, or for obtaining larger and well-formed crystals. In the former case, the vessel should be very shallow, but deeper for obtaining good crystals. As the operation requires time, it is better to cover the vessel with linen, muslin, or paper, to prevent dirt from falling in, although the use of these requires a longer time than otherwise. The vessel should be placed in a current of air.

c. The air containing moisture, some substances are placed in an enclosed space, together with oil of vitriol, chloride of calcium, caustic

lime, or potassa, or other absorbent material, an arrangement especially adapted to crystallize deliquescent bodies. The substance contained in a small capsule is placed over a shallow dish containing the absorbent, the whole put on a glass or porcelain plate, and covered with a bell-glass, the lower rim of which is made to fit more or less air-tight upon the plate, by grinding, by tallow, or in many cases without either. More convenient is it if the bell-glass be stoppered, so that the substance may be reached without removing the glass. The small capsule may rest upon a triangle of lead-wire, or on a low wine-glass, and after crystallization may be inclined to drain off the mother liquor.

d. *Evaporation in vacuo* is often resorted to, not only to hasten it by a diminution of pressure, but also where a substance might be injured by drying in the air. The vacuum is effected by an air-pump, and the substance usually placed above an absorbent, as in the preceding case. The most convenient arrangement is to have detached plates of ground plate-glass, with their ground bell-glasses, having a cap and stopcock to which a tube may be attached from the pump.

e. Where the air might act injuriously, and a vacuum is unnecessary, or where the vapor might injure an air-pump, a substance may be evaporated in another atmosphere, as in carbonic acid, or better in hydrogen gas. This is conveniently done in a tubulated retort, with its beak passing into a balloon, from the tubulure of which passes a glass tube drawn to a fine opening, and thrust through a cork. A glass tube entering the tubulure of the retort, airtight, is connected with an apparatus for evolving carbonic acid or hydrogen. (*Berzelius*.) Another method, by Liebig, is described in **ANALYSIS**, p. 197, § 130, and illustrated by fig. 1, Pl. II., where a substance is dried by the aid of heat.

Evaporating Vessels. They may be evaporating dishes or capsules, filtering glasses, crucibles, &c., made of metal, platinum, gold, silver, of porcelain or glass. Tin and tinned copper are employed in making pharmaceutic preparations. Copper, lead, and iron, are used in technical operations. For chemical purposes a platinum capsule is superior to any other evaporating vessel, and may be employed for nearly all purposes, except where chlorine or bromine are developed, where nitromuriatic acid is used. Gold may be similarly used with similar precaution. Pure silver is especially adapted to evaporating alkaline solutions, but is to be rejected for acid solutions. Next to platinum, porcelain is the most useful material for capsules, and should be as thin as practicable, proportioned to their size. Glass, although subject to fracture from sudden changes of temperature, is, nevertheless, very convenient, especially in the form of the filtering glass, fig. 10, p. 169, since digestion and other operations may be performed in the same vessel. The bottom of a retort, or portions of a flask cracked off by a hot iron or burning pastille, constitute good capsules. For minute operations, watch-glasses are found to be very convenient.

3. For technical purposes, lead and copper are chiefly employed, iron less frequently, and platinum only for concentrating sulphuric acid. The use of pure tin, porcelain and glass, is confined to making the finer chemical and pharmaceutical preparations, and the two last are used in refining gold and silver. For larger manufacturing purposes, lead is unquestionably the most suitable material, as it is easily wrought into any desired form, and is very slightly subject to corrosion, unless when heated with nitric, acetic, or muriatic acid, and even then its corrosion is trifling, especially if sulphuric acid or a sulphate be present. Evaporation may be performed by air, by fire direct, by water or steam, all under ordinary pressure, or by a diminution of atmospheric pressure.

a. *Spontaneous Evaporation* is resorted to in a few instances, the removal of the water being due to the air alone, or generally to the sun and air combined. In the manufacture of salt from salines, the weak brine being raised to the top of the graduating house or shed, is suffered to flow down in fine streams upon bundles of fagots, which divide it still more in its descent, and thus expose a large surface to the action of the wind. Weak salines, and sea-water on the coast, are also evaporated in very shallow wooden vats by simple exposure to the sun and air. Moist solids, glue, starch, &c., are dried by being placed in the air.

b. *Hot Air.* Montgolfier proposed in 1794 to evaporate vegetable juices which were very liable to fermentation, by driving through them air heated to 100° to 120° ; others have since employed hot air for evaporation, but generally with little success. M. Brame-Chevalier forced a current of hot air beneath the false bottom of a vessel containing syrup, and this bottom being perforated by minute holes, suffered the air to pass up through the solution, which was too thick to pass downward through the holes after the current of air ceased. The blast giving 10 cubic metres of air per minute, the air entered at 275° , and escaped at 200° , removing 30 kil. of water per minute, while the syrup remained at 165° to 175° . Montgolfier's method, at low temperatures, has latterly been applied to desiccating milk.

c. *Evaporation by fire direct* is the most frequently employed, although in most cases it is inferior in convenience to steam, and the amount of heat regulated with less certainty. The quantity of water evaporated is proportional to the tension of the vapor at different temperatures.

It is found that a square foot of surface, brought to ebullition (212°), will throw off 725 grains of water per minute with a tension of 30 inches of the barometer, which is about one lb. of water for every 10 square feet of surface. To know the quantity evaporated from a square foot of surface per minute at any other temperature, say 100° , we find by the table (see VAPOR), that the elastic force of vapor at that temperature = 1.86 inches of the barometer. Then $30 : 1.86 :: 725 : W = 44.95$ grains evaporated per minute at 100° . The quantity evaporated from each square foot of surface per minute, at any temperature below

212° , may be readily found by the following formula, in which t expresses the tension of vapor in inches of mercury at the required temperature, and is found by reference to the table of the tension of vapor; w is the weight of water required in grains. $w = 24\frac{1}{8} t$. But as the air always contains vapor of some tension, this should be ascertained, and subtracted from the tension found by the table, previous to multiplying it by $24\frac{1}{8}$. Thus, in the above case, where $t = 1.86$, suppose the vapor in the air to have a tension of 0.54, then $t = 1.86 - 0.54 = 1.32$, and the quantity evaporated at 100° would be 31.9 grains per square foot.

If evaporation is to take place at ebullition, extension of the surface of the liquid is of less importance than where a lower temperature is employed. The surface of the vessel should be partially covered, to prevent the return of vapor condensed by the colder air. Ure infers from experiment that thick metallic boilers rather accelerate than retard evaporation; and that over the fire direct, a roughened bottom and sides does not facilitate evaporation.

Various kinds of fuel are employed for evaporation, and with different results. It is not fully determined whether the amount of water evaporated is proportional to the fixed carbon, or to both the fixed and volatile carbon of fuel. It is certain that coals, anthracite, bituminous, coke, or charcoal, will evaporate double as much as an equal weight of wood. One convenience in wood over a flameless coal lies in the facility of throwing the heat to a great distance from the fire-place, under a very long pan or a series of boilers. The greatest economy is of course attained by making the flame circulate around a range of boilers, so that previous to the exit of the heated products of combustion, they circulate around a cold boiler. For convenience, a second boiler may be placed on a higher level, so that its heated liquid may be run into the adjoining boiler nearer the fire, for continuing or finishing evaporation. Due attention should be paid to setting a boiler, according to the nature of the fuel employed, so as to ensure a rather perfect combustion of the fuel before the gaseous matter reaches the cold metal, where it would otherwise deposit sooty matters. Where a smoky fuel is employed, some distance between the fire and boiler should be allowed, and even then small openings for the admission of a little air would prove advantageous to effect a more perfect combustion. In the case of anthracite and other flameless fuel, the distance between fire and boiler should be much less, and the coal may even be thrown directly under the evaporator in order to produce its full effect. See FUEL, for the evaporating power of wood, coal, &c. See PL. II., fig. 3, for a wort-boiler, described under BEER.

d. *Water-bath.* Many solutions, which would be injured by a temperature much above 212° , may be evaporated with safety by setting the evaporator in water, or one pan in another, and introducing water into the space between them. The lower pan being directly over the fire cannot be heated beyond 212° , if there be an escape-pipe for the steam

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generated. If a heat be required a little beyond 212°, it is effected by using a saline solution instead of water, and any given temperature below 300° may be thus attained. One advantage of such a solution is, that if not saturated at first, it becomes more so by the escape of steam, and its boiling point is raised; for in concentrating some liquids, a higher degree of heat is required for rapid evaporation. By observing the escape of steam from a small pipe, experience teaches the operative how to regulate his fire for boiling the saline solution. Where a uniform heat is required, water must of course be sup-

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plied to the saline bath in proportion as its water evaporates. The following table, by Legrand, from Gmelin, i., 239, shows the boiling points of saline solutions; the left-hand column showing the temperature of ebullition, the others the quantity of dry salts dissolved in 100 pts. water. Column 1 is chloride of calcium; 2, acetate of potassa; 3, carbonate of potassa; 4, acetate of soda; 5, nitrate of soda; 6, nitrate of potassa; 7, muriate of ammonia; 8, chloride of sodium; 9, carbonate of soda. At the bottom of the columns is the boiling point of the saturated solution, together with the quantity dissolved.

Boiling Point.	1	2	3	4	5	6	7	8	9
213.8°	10.0	10.5	13.0	9.9	9.3	12.2	7.8	4.4	
215.6°	16.5	20.0	22.5	17.6	18.7	26.4	13.9	7.7	7.5
217.4°	21.6	28.6	31.0	24.1	28.2	42.2	19.7	10.8	14.4
219.2°	25.8	36.4	38.8	30.5	37.9	59.6	25.2	13.4	20.8
221.0°	29.4	43.4	46.1	36.7	47.7	78.3	30.5	15.9	26.7
222.8°	32.6	49.8	53.1	42.9	57.6	98.2	35.7	18.3	32.0
224.6°	35.6	55.8	59.6	49.3	67.7	119.0	41.3	20.7	36.8
226.4°	38.5	61.6	65.9	55.8	77.9	140.6	47.3	23.1	41.0
228.2°	41.3	67.4	71.9	62.4	88.3	163.0	53.5	25.5	44.7
230.0°	44.0	73.3	77.6	69.2	98.8	185.9	59.9	27.7	47.9
231.8°	46.8	79.3	83.0	76.2	109.5	209.2	66.4	31.8	
233.6°	49.7	85.3	88.2	83.4	120.3	233.0	73.3	35.8	220.3°
235.4°	52.8	91.4	93.2	90.9	131.3	257.6	80.8	39.7	48.5
237.2°	55.6	97.6	98.0	98.8	142.4	283.3	88.1	40.2	
239.0°	58.6	103.9	102.8	107.1	153.7	310.2			
240.8°	61.6	110.3	107.5	115.8	165.2		237.6°		
242.6°	64.6	116.8	112.3	125.1	176.8		88.9		
244.4°	67.6	123.4	117.1	134.9	188.6				
246.2°	70.6	130.1	122.0	145.2	200.5				
248.0°	73.6	136.9	127.0	156.1	212.6				
251.6°	79.8	150.8	137.0	175.3					
255.2°	86.2	165.1	147.1	204.5	249.8°				
258.8°	98.2	180.1	157.3		224.8				
262.4°	92.4	196.1	167.7	256°					
266.0°	104.6	213.0	178.1	209.0					
269.6°	110.9	230.6	188.8						
276.8°	123.5	267.5							
284.0°	136.3	308.3	275°						
291.2°	149.4	354.9	205.0						
298.4°	163.2	407.9							
305.6°	178.1	467.6							
312.8°	194.3	534.1							
320.0°	212.1	607.4							
327.2°	231.5	687.6							
334.4°	252.8	775.0							
341.6°	276.1								
348.8°	301.4	336.2°							
355.1°	325.0	798.2							

e. Evaporation by steam has many advantages over all other methods. 1. A single fire and chimney is sufficient to heat a large number of vessels. 2. Steam may be conveyed to any required point by pipes, with little loss by condensation. 3. The supply of steam to an evaporator may be regulated with ease, and a greater or less degree of heat obtained for vaporization or evaporation. 4. Neither the evaporating vessel, nor the vegetable or other substances in solution, can be injured, as the temperature does not rise much beyond 212°. 5. A somewhat higher temperature may be attained by increasing the pressure in the

steam-boiler; thus at the high pressure of 60 inches, or 2 atmospheres, the temperature of the steam would be about 250°. Against the use of steam may be urged the greater cost of the arrangement, and the loss of heat by conveyance to a distance, but there is equal or greater cost in maintaining many different fires, and loss by conveyance is obviated by wrapping the steam-pipes.

Steam exhibits no higher temperature than water from which it rises, but the quantity of heat which it contains is much greater. A cubic inch of water becomes a cubic foot of steam, or more exactly, 1694 cubic inches. If

it require one hour over a steady fire to heat a volume of water from 32° to 212° , it will require $5\frac{1}{2}$ ($5\frac{1}{2}$) hours to boil it off over the same fire; consequently, there has entered into the steam $180^{\circ} \times 5\frac{1}{2} = 1000^{\circ}$, which is termed latent heat, and is given off when the steam is condensed. If condensed in cold water, 1 lb. of steam will heat $5\frac{1}{2}$ lbs. of water from 32° to 212° , and nearly the same effect is obtained by condensing it in tubes which circulate in the water. But equal weights of vapor at any temperature contain equal quantities of heat, for where the sensible heat is lower, the latent heat is proportionally higher, and hence there is no economy of fuel in employing temperatures below ebullition. The quantity evaporated by steam is the same as by fire direct, 10 square feet of surface in the evaporator throwing off about 1 lb. of water as steam.

The methods of applying steam are by passing the steam-pipes into the liquid, or into a steam casing. In the former case, the pipe should circulate at least once around the evaporator, if nearly all the heat of condensation is to be saved, and a spicket should be attached to the lowest level of the pipe for running off condensed water. The casing around an evaporator may be of wood, lead, copper, or iron, but the first is apt to leak and the metals radiate heat externally. To obviate the last objection, the metallic casing may be surrounded with wood.

f. Evaporation in Vacuo. It has been stated (1, b) that ebullition takes place at lower temperatures under diminished pressure, and hence evaporation may be conducted rapidly, and without fear of injury by heat to the organic substances in solution. This is effected in two ways. The air-tight evaporator is filled with steam, to expel the air, and the access of steam being stopped, a tube is opened, which connects with a cold-water condenser, thus effecting a more or less perfect vacuum. Steam admitted to the double casing of the evaporator, produces ebullition at a very low temperature. The other method is to drive steam into the case, or jacket, as before, and to pump out air and steam by an air-pump driven by a steam-engine. See *SUGAR*. It appears, from Kuhlmann's experiments, that the vacuum principle may be applied to other purposes with advantage. While sulphuric acid from the lead-chambers may be concentrated by evaporation in leaden boilers to 61° Baume, at ordinary atmospheric pressure, it can be brought to 66° B. in vacuo, without subjecting the lead to any more corrosion than what ordinarily occurs.

EXCREMENTS. Those portions of animal food which, being non-digestible and insusceptible of absorption, are ejected from the body in a solid form, more or less mixed with fœtid secretions of the intestines. In a general sense, the term applies to both fœces and urine. The evacuating organs of birds discharge both the liquid and solid excrement through one conduit, and hence the presence of urea in the dung of birds, for example, in **GUANO**.

The excrements of man contain about 25

pr. ct. of solid matter, very little of which is soluble in water. This solid portion varies with the nature of the food, and differs in different animals. Those of man and the herbivora, says Liebig, contain little or no bile; and of the dog, none at all, these latter being phosphate of lime; the coloring matter is distinct, and, excepting a small portion, is insoluble in alcohol. The excrements of man consist of woody fibre, fatty, resinous, and waxy substances, and the insoluble salts of the food, phosphate of lime, and magnesia, with some silica, and traces of soluble salts. Their fertilizing value is due to these salts, and to the ammonia generated by putrefaction from the nitrogen which they contain. The ashes of dry human excrements amount to about 15 pr. ct., and consist of the silica and earthy salts.

EXPANSION. *Phys. Chem. Tech.* The enlargement of a body without change of its chemical constitution, is effected by heat or mechanical means. We shall confine ourselves to the former. In general all bodies expand when heated, and that in proportion to the amount of heat; but some few contract between certain temperatures, otherwise, following the general law of expansion, and excepting gases, each substance seems to have its peculiar rate of expansion. Expansion is in general greatest with gases, less with liquids, and least with solids.

1. *Expansion of Gases.* All gases expand equally for equal increase of temperature, and the expansion is in direct proportion to the temperature. According to the experiments of Gay-Lussac, 1000 vols. of air became 1375 when heated from 32° to 212° ; but Rudberg's results, now more generally received, give the expansion as 365. According to the last results, 1000 vols. expand $\frac{365}{180} = 2.028$ for each

degree, or $\frac{1}{48.3}$ of the volume at 32° . Vapors, in general, follow the same rate of expansion.

Since gases and vapors are measured to determine their weight, and their specific gravities usually reduced to the temperature of 32° , the following formula will be found convenient for reduction from the observed volume and temperature, to the volume at 32° . Denoting by V the measured volume at t temperature, and V' , the volume at 32° ,

$$V' = \frac{493 V}{493 \pm (t - 32)}$$
 Thus, if we measured 234 vols. of dry carbonic acid at 75° , the formula would be $V' = \frac{493 \sqrt{234}}{493 + 43} = 215.23$ vols.

at 32° . A more general formula to reduce a known volume, V , at temperature, t , to another volume, V' , at t' temperature, is
$$V' = V \frac{493 \pm (t' - 32)}{493 \pm (t - 32)}$$
 When $t' = 32^{\circ}$, the latter is the same as the preceding formula.

Various applications are made of the expansion of gases by heat. When air is heated it becomes specifically lighter than surrounding air, and rises, as may be observed, by the eddy of intermingling currents over a heated body, lamp, or fire-place. The ascending current confined to a chimney produces the draft.

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On the greater levity of heated air was founded the first balloon, which consisted of a large bag filled with air, and heated by a fire beneath the lower opening. The air THERMOMETER measures temperature by the expansion of air.

2. *Expansion of Liquids.* Liquids expand much less than gases, but each liquid has its peculiar rate of expansion, nor has any general law been observed. The usual mode of comparing, is by observing the rate of expansion from given temperatures, as between 32° and 212° , but Gay-Lussac observed their contraction, on cooling a certain number of degrees, from their respective boiling points, where they are all in the same molecular condition. The following table, where the volume of the liquid at its boiling point is assumed to be 1000, shows the relation of contraction thus found by Gay-Lussac.

Cooled through	Contraction of			
	Water.	Alcohol.	Sulph. Car.	Ether.
9°	3.34	5.55	6.14	8.15
18°	6.61	11.43	12.01	16.17
27°	10.50	17.51	17.98	24.16
36°	13.15	24.34	23.80	31.83
45°	16.06	29.15	29.65	39.14
54°	18.85	34.74	35.06	46.42
72°	24.10	45.68	45.77	58.77
90°	28.56	56.02	56.28	72.01
108°	32.42	65.96	66.21	
126°	35.47	75.48		

Water boils at 212° , alcohol at 173° , bisulphuret of carbon at 134° , and ether at 96° . An interesting relation is thus shown between alcohol and bisulphuret of carbon, although they differ in constitution, specific gravity, and other properties.

Temperature by Air Thermom.	Expansion of Mercury for 180° .	
	Real.	Apparent.
212°	1 pt. in 55.50	1 pt. in 64.80
392°	" 54.25	" 63.78
572°	" 53.00	" 63.18

The use of mercury in many physical researches, demands that its expansion should be accurately determined. The experiments of Dulong and Petit are the most reliable,

Liquids.	Expansion from 32° to 212° .	Observer.
Mercury (real expansion).....	0.018018	Dulong and Petit.
" (apparent in glass).....	0.015432	"
Water (from 39.2° to 212°).....	0.042133	Hällström.
Sea-water (artificial)	0.0442098	Muncke.
Sulphuric acid (sp. gr. = 1.836).....	0.0578495	"
Oil of turpentine	0.0700000	Dalton.
Oil of almonds.....	0.0787005	Muncke.
Fat oils	0.0800000	Dalton.
Nitric acid (sp. gr. = 1.4405)	0.1148853	Muncke.
<i>Expansion from 32° to</i>		
Ammonia (sp. gr. = 0.9465) 113°	0.0198310	"
Muriatic acid (gr. = 1.1978) 113°	0.0253598	"
Ether (gr. = 0.733) 104°	0.0635235	"
Bisulphuret of carbon 149°	0.0809663	"
Naphtha (gr. = 0.78125) 203°	0.1060059	"

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although they employed the air-thermometer as a standard, and adopted Gay-Lussac's results for the expansion of air, 375 . (See preceding §).

A few liquids possess the property of contracting by heat from a certain point, and then expanding by an increase of temperature; in other words, they have a point of greatest density. Water is the most important of these liquids. From the experiments of Hällström, Muncke, Despretz, and others, its point of maximum density is between 39.2° and 39.4° ; the former is most probably correct. According to Hällström's experiments, the true expansion of water is as follows, assuming the density and volume at $39.38^{\circ} = 1$. These results differ but little from those of Despretz.

Temp.	Density.	Volume.
32°	0.9998918	1.0001082
35.6°	0.9999417	1.0000281
39.2°	0.9999995	1.0000002
39.38°	1.0000000	1.0000000
41°	0.9999950	1.0000050
50°	0.9997825	1.0002200
59°	0.9992647	1.0007357
68°	0.9984534	1.0015490
77°	0.9973587	1.0026483
86°	0.9959917	1.0040245

The expansion of saline solutions is also irregular, and depends on the nature and quantity of salt in solution. The results obtained by different observers on the maximum density of saline solutions are too variable to allow of accurate conclusions, but it would seem that sea-water has its maximum density below 32° . From many well-conducted experiments on solutions of different salts, Despretz draws the conclusions: 1, that all saline solutions have a maximum of density; 2, that this point sinks more rapidly than the point of congelation; 3, that the sinking of the freezing point below 32° , and of the maximum-density point below 39.2° , is nearly proportional to the quantity of salt in solution.

The following table, from Muncke's experiments, exhibits the expansion of a few liquids, when heated from 32° to 212° , or less, their volume at $32^{\circ} = 1$.

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From the last of the preceding tables, it is evident, that liquids possess very different powers of expansion, the more volatile being in general the more expansible; but from the first table, a similarity of contraction being shown between two different bodies, alcohol and bisulphuret of carbon, it is probable that similar relations will be found between others, when examined in a similar manner. From the second table, the expansion of mercury is shown to be greater for 180° above the boiling point of water than for the 180° below that point, and still greater for the third 180° . This fact has an important bearing on the *Thermometer*. The singular irregularity of water exhibited in the third table, has an important meteorological and physiological bearing, since upon it depends, in some measure, the preservation of life in the waters and on the land in the temperate and colder zones of the earth. Should the water of a river or lake continue contracting by cold, the colder stratum formed at the top would sink, and a warmer rise to occupy its place, until the whole would reach 32° , when ice is formed. Now, where other liquids continue to contract to congelation, the solid which forms sinks in the liquid; so that ice would sink in water at 32° , and thus the whole mass of water, in fresh water lakes and rivers, would be rendered solid. But water, reaching its maximum density at 39.2° , the upper stratum, which reaches that temperature only, will sink, and when the cooling of the surface continues, the water expands, and remains at the top, even when it congeals. Hence, at some depth below the surface of water, even in high latitudes, the temperature cannot fall below 39.2° .

A few liquids, produced by the compression of gases, seem to expand much more than others, and liquid carbonic acid expands even more than the gaseous acid; 100 volumes of

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liquid carbonic acid becoming 145 when heated from 32° to 86° . (*Thilorier*.) Liquid sulphurous acid and cyanogen are also much more expansible than other liquids, but less so than carbonic acid. *Kemp*.

3. *Expansion of Solids*. All solids expand by heat, but in a less degree than liquids, and, like the latter, they expand in a greater degree with increasing temperature. But this increase in dilatation is so slight, especially with those of a high fusing point, that in nearly all cases it may be neglected. If, however, we were to employ iron to measure higher degrees of heat at the true temperature of 572° , it would indicate $702\frac{1}{2}^{\circ}$, and even platinum, which expands more uniformly at 572° , would indicate 593° . It should also be observed, that a few solids exhibit the phenomenon of greatest density at certain temperatures. Thus, fusible metal, composed of 2 pts. bismuth, 1 pt. tin, and 1 pt. lead, and fusing at about 201° , expands by heating from 32° to 111° , then contracts to 158° , its point of greatest density, after which it regularly expands.

The expansion of a solid may be viewed in reference to its lengthwise or linear expansion, or to its cubical dilatation, for most solids expand uniformly in all directions. Hence, if the volume, as well as length of a body at 32° , be put = 1, its volume at a higher temperature = v , and its length l , then $1 + v = (1 + l)^3 = 1 + 3l + 3l^2 + l^3$; but as l is minute in slight differences of temperature, its higher powers may be neglected, or $1 + v = 1 + 3l$. The increase in volume is therefore three times the linear expansion.

The following table, chiefly from L. P. and W.'s *Wörterbuch d. Chemie*, exhibits the linear expansion of many solids, from which their cubical dilatation is easily obtained by multiplying by 3, according to the above formula. The length at $32^{\circ} = 1.0000000$.

Substances	Linear Expansion from 32° to 212° .		Authority.
	Decimals.	1 part in	
Pottery, brown English.....	0.00012000	8333	
“ porous, made from charcoal.....	0.00004000	25000	
Marble, from St. Beat.....	0.00041810	2391	Destigny.
“ “ Carrara.....	0.00084870	1178	“
“ “ Solst.....	0.00056849	1769	“
Stone, from St. Pernon.....	0.00043027	2304	“
“ “ St. Leu.....	0.00064890	1541	“
Glass, English flint.....	0.00081166	1248	Lavoisier.
“ French flint.....	0.00087199	1147	“
“ white.....	0.00083333	1200	Smeaton.
“	0.00094400	1059	Herbert.
“	0.00099100	1009	Berthoud.
“	0.00086100	1161	Dulong.
“ tube.....	0.00077615	1288	Roy.
“ “ from St. Gobain.....	0.00089089	1122	Lavoisier.
“ “ common, without lead.....	0.00087572	1142	“
“ “	0.00089760	1114	“
“ “	0.00091751	1090	“
“ “ thin.....	0.00092100	1085	Horner.
“ rod.....	0.00080787	1237	Roy.
“ “	0.00091900	1088	Horner.
“ “	0.00092500	1081	“
“ from 32° to 212°	0.00086130	1161	Dulong and Petit.
“ “ 212° to 392°	0.00091827	1089	“
“ “ 392° to 572°	0.000101114	987	“

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Substances.	Linear Expansion from 32° to 212°.		Authority.
	Decimals.	1 part in	
Deal wood	0.00077615	1289	Roy.
Platinum	0.00085655	1167	Borda.
“	0.00099180	1008	Troughton.
“	0.00085700	1157	Morveau.
“	0.00088417	1131	Dulong and Petit.
“	0.00090000	1111	Wollaston.
Palladium	0.00100000	1000	“
Charcoal, from pine.....	0.00100000	1000	Heinrich.
“ “ oak	0.00120000	833	“
Antimony.....	0.00108330	923	Smeaton.
Cast iron bar	0.00110940	901	Roy.
Steel bar.....	0.00116000	862	Lavoisier.
“ “ Styrian	0.00115200	868	Horner.
“ “ from Schaffhausen	0.00111200	899	“
“ hardened.....	0.00122500	816	Smeaton.
“	0.00137500	727	Berthoud.
“ “ tempered at 100°	0.00136900	730	Lavoisier.
“ “ “ “	0.00138600	721	“
“ “ “ 178°	0.00123956	807	“
“ soft.....	0.00107500	930	Ellicot.
“ “	0.00189900	840	Troughton.
“ “	0.00115000	869	Smeaton.
“ “	0.00107875	927	Lavoisier.
“ “	0.00107956	925	“
“ “	0.00110400	905	Berthoud.
“ “	0.00114470	873	Roy.
Iron	0.00114600	872	Ellicot.
“	0.00117200	853	Herbert.
“	0.00119200	838	Berthoud.
“	0.00110000	909	Morveau.
“ wrought	0.00122045	819	Lavoisier.
“ “	0.00125833	794	Smeaton.
“ “	0.00115600	865	Borda.
“ “	0.00115600	865	Tralles.
“ “	0.00114560	872	Schwerd.
“ “	0.00111155	899	Augustin.
“ “	0.00111545	896	“
“ “	0.00112330	890	“
“ “	0.00114550	872	“
“ “	0.00144600	691	Hällström.
“ “	0.00118203	846	Dulong.
“ “	0.00116800	856	Horner.
“ “ slightly hammered.....	0.00122045	819	Destigny.
“ wire	0.00114010	877	Troughton.
“ “	0.00123504	812	Lavoisier.
“ “	0.00118210	846	Dulong and Petit.
Gold.....	0.00140100	713	Ellicot.
“	0.00131100	762	Berthoud.
“	0.00147500	677	Morveau.
“ fine, from parting.....	0.00146606	682	Lavoisier.
“ unannealed	0.00155155	645	“
“ annealed.....	0.00151361	660	“
Bismuth	0.00139167	718	Smeaton.
Copper	0.00171000	584	Ellicot.
“ hammered.....	0.00170000	588	Smeaton.
“ “	0.00191880	521	Troughton.
“ “	0.00179000	558	Morveau.
“ “	0.00178400	560	Borda.
“ “	0.00172244	581	Lavoisier.
“ “	0.00171222	584	“
“ “	0.00171822	582	Dulong.
Brass.....	0.00182300	548	Ellicot.
“	0.00193332	517	Smeaton.
“ wire	0.00187821	532	Despretz.
“ “	0.00188500	530	Herbert.
“ cast.....	0.00187500	533	Smeaton.
“ “	0.00193400	517	Berthoud.

EXPANSION.

EXPANSION.

Substances.	Linear Expansion from 32° to 212°.		Authority.
	Decimals.	1 part in	
Brass, cast.....	0.00186671	535	Lavoisier.
“ “.....	0.00188971	529	“
“ rod, English.....	0.00189280	528	Roy.
“ Hamburg.....	0.00185540	538	“
“ plate, Tyrol.....	0.00190300	525	Horner.
Bronze, copper 8 + tin 1.....	0.00181667	550	Smeaton.
Speculum metal.....	0.00193333	517	“
Silver.....	0.00197800	505	Ellicot.
“ “.....	0.00207000	483	Herbert.
“ “.....	0.00190500	524	Berthoud.
“ “.....	0.00198800	503	Morveau.
“ “.....	0.00208260	480	Troughton.
“ from Cupel.....	0.00199740	524	Lavoisier.
“ “ Parisian.....	0.00198680	524	“
Solder, 2 copper + 1 zinc.....	0.00205833	485	“
Ice.....	0.00245120	407	Heinrich.
Tin, common.....	0.00248330	407	Smeaton.
“ fine.....	0.00228330	438	“
“ “.....	0.00232200	430	Herbert.
“ “.....	0.00255700	391	Berthoud.
“ “.....	0.00216400	462	Morveau.
“ “.....	0.00209300	477	Horner.
“ from Falmouth.....	0.00217298	460	Lavoisier.
“ “ Malacca.....	0.00193267	516	“
Soft solder, 2 lead + 1 tin.....	0.00250533	399	Smeaton.
Lead.....	0.00288200	345	Ellicot.
“ “.....	0.00286667	348	Smeaton.
“ “.....	0.00287300	348	Herbert.
“ “.....	0.00308600	324	Berthoud.
“ “.....	0.00271900	367	Morveau.
“ “.....	0.00284836	351	Lavoisier.
“ “.....	0.00290200	344	Horner.
Zinc cast.....	0.00294167	339	Smeaton.
“ “.....	0.00305100	328	Morveau.
“ “.....	0.00296800	337	Horner.
“ lengthened $\frac{1}{12}$ by hammering.....	0.00310833	322	Smeaton.

The different results given in the above table for the same substances are due to errors of observation, to a somewhat differing chemical constitution, and to a different physical condition in the same substance.

Mitscherlich observed, that all homogeneous solids, and all crystals of the regular system, expand equally in all directions, but that all crystals belonging to the other systems expand unequally in different directions, and that in some instances there is expansion in one direction and contraction in another. Thus, in calcareous spar, he found the linear expansion in direction of the main axis from 32° to 212° = 0.00286, while in the direction of the lateral axes, the contraction was 0.00056; hence, the obtuser edges of the rhomb, measuring 105° 4', at 50°, became by heating, 8½' acuter, and the acute edges became correspondingly more obtuse. This unequal expansion may be easily shown by gluing two plates of gypsum together, so that their axes are at right angles to each other, and heating them, when they become curved. (Fresnel.) Mitscherlich measured the altered angles of twin crystals by the reflections of their surfaces, and applied this method to gypsum, calc spar, arragonite, bitter spar, heavy spar, &c.

The expansion of solids by heat demands

attention in the arts, from its interfering in mechanical arrangements, and its being often made available for utility. Thus, when a wheel-tire of iron, being made a little smaller than the circumference of the wheel, and expanded by heat, is put upon the wheel, upon cooling it, the contraction of the iron not only secures it in its position, but binds all parts of the wheel firmly together. The heavy walls of a building in Paris, which were spreading, were brought again to their vertical position by passing iron bolts, with screws on one end, through the opposite walls, heating the bars, and screwing up the nuts in proportion to the expansion; on contracting, the walls were drawn to their upright position. In the construction of machinery, where parts are to be heated, it is often necessary to bear in mind the expansion of the heated parts, as well as the different expansibility of two metals. Allowance must be made for expansion in laying iron rails, and in setting iron bars in heavy masonry; for the alternate expansion and contraction of the former would tend to loosen the rails, and, in the latter, to loosen the courses of stone. Daniell has employed the expansion of a platinum rod to indicate high degrees of temperature, such as furnace heat; and Borda employed the different expansibilities of two metals to indicate temperature.

See THERMOMETER. The compensating pendulum is constructed on a similar principle. A pendulum, composed of a single metallic rod, is liable to fluctuation in the time of its vibrations, from its expansion or contraction by heat or cold. But by the use of several rods of different metals, having different expansibilities, so arranged, that while one set of rods lengthen the pendulum, another set shortens it equally, and thus keeps it of equal absolute length in all ordinary changes of temperature.

EXTRACTS. *Chem. Tech. Phar.* The term *extract* applies to the inspissated juice of organic substances, containing all those portions of the material acted upon which are soluble in the menstruum used, and are obtained by DECOCTION, MACERATION, DISPLACEMENT, or INFUSION; hence the classification into aqueous, alcoholic, and ethereal extracts. The object of extracts is to comprise in a condensed bulk the active principle of a vegetable substance, unaltered, and in its natural state of combination, and the first consideration in their manufacture should be, what solvent is most proper to separate the useful parts of the plant from those which are inert. Burin proposes the general use of alcohol, of 0.834, but Souberain thinks it more advantageous to substitute that of 0.921. In extracting the soluble substances contained in vegetable matter, it should not be forgotten, that the solubility peculiar to each of their isolated principles is no longer the same when several are associated together, and that we should not judge, *à priori*, of the action of solvents on each of them. Mohr, in his scientific essay upon the mode of preparing pharmaceutical extracts (*An. der Pharm.* vol. 31), asserts, that boiling is unnecessary, and tends to produce an inferior extract. The dissolved matter, he says, is constantly altered during evaporation, and that the more water to be evaporated, the more is the extract depreciated. The solution, therefore, should be made by displacement, because, in large operations, the first and more concentrated liquors need only be evaporated, as the last and weaker can be reserved for percolating through new material. In operating upon small quantities of material, where it will be inconvenient to use the weaker liquors, the better way will be to infuse it in the menstruum, and then, to save loss, submit it to pressure in an apparatus of convenient construction, and represented by fig. 43, p. 523.

The evaporation of the liquid solution should be conducted so as to avoid the decomposing power of heat, air, and water upon its organic contents. A preferable method is by a steam-bath, for then the process is gradual, and without danger of impairing the efficacy of the active principles of the plant, some of which are entirely destroyed by a temperature above 212°. In those instances, where alcohol or ether has been used as the solvent, they should be recovered again by distillation over a water-bath. The so-called pneumatic extracts, which are said to be superior, because evaporated *in vacuo*, owe their fresh green color to the presence of chlorophyll, a resinous coloring matter peculiar to all plants, but

Dr. Meurer (*Archiv. der Pharm.*, 1843), doubts their boasted excellence, for, says he, the preservation of the coloring matter unaltered does not allow the inference that all the constituents are equally unimpaired, for that some lose their efficiency in drying, even where no increase of temperature occurs, and where the coloring matter remains unaltered. The best method, therefore, is that designated in this article—evaporation over a steam or water-bath.

EXTRACTION. A term applied to the separation of the soluble portions of a substance by either of the processes of DISPLACEMENT, SOLUTION, DECOCTION, MACERATION, or INFUSION.

EXTRACTIVE MATTER. *Chem.* Previous to late examinations, the term *extractive* was indiscriminately applied to a number of substances yielded by vegetables to solvents. Extractive, in its present sense, is the heterogeneous compound formerly considered by Fourcroy as the basis of all extracts, and consisting of ingredients varying with those of the plant from whence obtained. It precipitates spontaneously during the gentle evaporation of aqueous extracts. Its color is brown or brownish black, and though very slightly soluble in cold water, dissolves readily in alkaline solutions. Previous to oxidation by exposure, and in its fresh state, it is soluble in alcohol and water also, but insoluble in ether, and is precipitated by the alkalies and metallic oxides. In dyeing operations, it forms with alumina the basis of many colors. By the action of air upon solid animal or vegetable matters, a similar pulverulent brown substance, HUMUS, is formed.

F.

FÆCES. See EXCREMENT.

FAHLUNITE. *Min.* Triclasite. Cryst. 6-sided prisms, with perfect basal cleavage. $H. = 3$. $G. = 2.6 - 2.79$. Green, passing into dark brown and black; resinous or vitreous; opaque; streak grayish white.

Chem. Relat. Alone in a tube it gives off water; on charcoal it burns white, and fuses on the edges to a white, blebby glass; soluble in borax and mic. salt, with a yellow iron tint, and leaving a siliceous skeleton in the latter; not dissolved by soda nor acids. Form. $3 RO, 2 SiO_3 + 3 (Al_2O_3, SiO_3) + 6 HO$, ($MS_2 + 3 AS + 2 aq$), in which the RO is magnesia, soda, potassa, and protoxides of iron and manganese; while the alumina is partly replaced by sesquioxide of iron. It occurs in the Eric Mats mine, near Fahlun, Sweden. For Hard Fahlunite, see CORDIERITE.

FARINA. *Syn. Fr.* Farine. *Ger.* Mehl. A term applied to the ground and sifted powder of seeds and roots, whose basis is fecula. It is derived from *far*, Lat., *grain*, the meal of which most generally takes the appellation. Farinaceous food refers to the edible parts of those plants, which, when powdered, constitute a nutritious flour. See FLOUR and STARCH.

FASSAITE. See AUGITE.

FATS. *Chem. Tech.* The term fats or fatty matter applies to those inflammable bodies whose chief characteristic is an unctuous touch. The variable consistence of fats has induced their classification, regardless of their source, into **OILS**, **BUTTERS**, and **SUETS**. The former are the most fluid, the latter the most solid of the three, whilst the second class holds a medium position. All these fats were originally, and for some time considered as simple products; but the researches of Chevreul and Braconnot have corrected this erroneous idea, by developing experimentally but accurately, the actual constituents of most fats, showing them to be compound bodies formed partially of liquid, and partially of solid ingredients; these components, however, varying proportionally in the different fats.

The fluid constituent is **OLEIN**, an unerring verification of the presence of which, in fats, is the formation of sebacic acid by their distillation; but the solid portion of the animal greases generally consists of two distinct principles, **MARGARIN** and **STEARIN**, though in some instances one or the other is wanting. For example, the former comprises entirely the more consistent part of human fat, whereas, in most vegetable greases, the solid portion is so exclusively of margarin, that this principle is somewhat characteristic of them, stearin being seldom found associated with it under such circumstances. But olein, margarin, and stearin are only the *proximate* constituents of fats; for their *ultimate* components, scarcely varying in any of them, are carbon, hydrogen, and oxygen. The proximate components above named are not universally the same in all fats; for among these latter there are a few of peculiar physical and chemical properties, the solid principle of which slightly differs from that of others; thus, for instance, in **PALM OIL**, crystalline *palmitin* occupies the place of stearin in tallow; so also *celin* in **SPERMACETI**. All these components are themselves compound bodies, being positive and definite chemical unions of their several natural fatty acids with a natural base. This base, in most cases, is **GLYCERIN**, though in some instances, spermaceti for one, *ethal* takes its place (See **CETYL**), and the presence of the former is always proved when the tested fat on being boiled yields **ACROLEIN**, $C_3H_4O_2$ (see **GLYCERIN**), a pungent gaseous body. These fatty acids, by changing the termination of its title into *ic*, take the name of the compound which yields them; thus the acid in olein is called oleic acid. They differ in their properties, and are distinguishable by certain characteristics peculiar to each. When pure, the acids and their natural compounds are scarcely alterable in the air; the rancidity assumed by fats on exposure being due to absorption of oxygen from the atmosphere, chiefly in consequence of impurity in the fats. In some fats, as in that of the goat, volatile acids exist ready formed, and to them is due the peculiar natural scent of such greases. Pure olein, margarin, and the like, are perfectly inodorous and less alterable in the air, because all their volatile associates have been dissipated and removed during their purification.

Vegetable fats exist mostly in the pulpy envelop of the seeds, whilst animal fat is found secreted in the *fat cells*, in the cavities of the cellular tissue. Intervening the muscular fibres, between the skin and the flesh, around the kidneys and within the abdominal cavity of the omentum, it is most abundant. In the species of whale, the bony cavity of the head is the receptacle of the secreted spermaceti, and in the case of butter, it is mixed in a liquid state in milk. The molecular formation of fat was first announced by Braconnot and Raspail, who have proved that animal fats consist of small microscopic particles enclosed in sacks, a number of which conglomerated together, form a mass. Crumbling the whole in cold water between the fingers, separates these granules which are readily removable, free of membranous matter and water, by means of a sieve. As to their origin and the means by which they are stored in those receptacles from which we extract them, we remark that the living plant is as much indebted to food for the support of life, as is the living animal; and the presence of fat in either instance is an evidence of the conversion or assimilation of a part of the elements of their nourishment into those constituents of which it is naturally formed. Assimilation, or the process of formation or growth, says Liebig, goes on in the same way both in animals and vegetables, and the formation of fat in either is owing to the same cause, and that is, the separation of oxygen from the elements of food.

As regards the formation of animal fat, there are two chemical theories; one explaining its production by the conversion of the non-azotized ingredients of food, such as starch, sugar, and the like, by the processes of digestion and assimilation; the other averring that it is not generated in the animal frame, but exists already formed in the manifold products of the vegetable kingdom, serving as food. This latter supposition is advanced and supported by Boussingault, Dumas, and Payen, the former by Liebig and others.

Blondeau has observed a curious transformation of casein (cheese) into fatty matter. Although the cheese contained but $\frac{1}{500}$ of its weight of fatty matter extractable by alcohol and ether, when kept for 2 months in a cellar, it was almost wholly transformed into a fat resembling butter, from which the unaltered casein was separated by water. Progressive observation showed, that the change was accompanied by the development of several species of mycoderminous plants, all of which were nitrogenous. Blondeau observes, that by removing ammonia from casein, the remainder has a composition analogous to fatty bodies; which is a rather hasty conclusion; but if nitrogen and a little carbonic acid be abstracted, the remainder certainly resembles the composition of fats. Blondeau farther found fibrin similarly transformable, as all proteic compounds probably are. The formation of adipocire is probably due to a similar transformation. *Comptes Rendus*, xxv. 360.

Prop. Fats are insoluble in water, more or

FAUJASITE.

less soluble in alcohol, and readily so in ether. The saponifiable fats are of both vegetable and animal origin, but some are more susceptible of this process than others. The compounds which they produce by union with soda and potassa, are called soluble **Soaps**; those with ammonia are termed, by Boullay, amides of the fat acids. Their analogous combinations with the alkaline earths are insoluble soaps, as are also their compounds with metallic oxides, generally known as plasters.

The action of the different stronger acids upon fat oils is recorded under each respectively, and under the head of their different components, referred to in this article. For a practical view of them and their relations, see "*Morfit's Applied Chemistry.*"

FAUJASITE. *Min.* Cryst. square 8-hedra; scratches glass easily; $G = 1.923$; brown, vitreous, uneven fracture. It yields much water in a tube; on charcoal swells up and fuses to a white enamel; fuses with a little soda, with effervescence to a colorless, transparent glass; decomposes with muriatic acid. Form. $3 \text{CaO}, 4 \text{SiO}_3 + 3(\text{Al}_2\text{O}_3, 2 \text{SiO}_3) + 24 \text{HO}$ (*Damour*). It differs in composition from zeolites, approaching to that of harmotome (*Ram*). Occurs in the Mandelstein of Kaiserstuhl, in Breisgau.

FAYALITE. *Geol.* A complex volcanic scoria, from the Azores, containing a very large proportion of protoxide of iron.

FEATHERS. The external covering or plumage of birds. Their composition is similar to that of horn, though, according to Scherer's analysis, they contain one eq. less of oxygen than that body. When dissolved in and heated with potash ley, ammonia is eliminated and a solution formed, which, upon neutralization with acetic acid, gives a white, gelatinous precipitate, **PROTEIN**. (?) Additional to carbon, hydrogen, and nitrogen, they contain minute portions of sulphur and phosphorus. (?) Scherer's formula for feathers is $\text{C}_{48}\text{H}_{39}\text{N}_7\text{O}_{16}$. According to Besanez, the beard of feathers generally yields a large proportion of silex in the ashes, averaging about 33 pr. ct.; the quill a much smaller quantity, and the pith none. They contain also iron, phosphate of lime, basic phosphate of soda, but neither sulphates nor chlorides.

FEATHER ORE. *Min.* Occurs in capillary threads. Melts and fumes in a candle-flame; fuses on charcoal, and may be almost wholly volatilized in white fumes; in an open tube gives a white, volatile sublimate of oxide of antimony, and one not volatile, of antimonite of lead; soluble in heated muriatic acid. Form. $\text{PbS}, \text{SbS}_3 + \text{PbS}$ (*Rose*). Local. Wolfenberg, Harz.

FECULA. See **STARCH**.

FELDSPAR. *Min. Syn.* Orthotomous feldspar, *M.*; Felspar; Orthoclase, Orthose, Adularia, Amausite, Amazonstone, Glassy, *F.*, Icespar, Leelite, Moonstone, Murchisonite, Napoleonite, Necronite, Variolite. *Ger.* Feldstein, Feldspath, Eisspath, Mondstein.

Descrip. Cryst. oblique rhombic; secondary forms very numerous; cleavage perfect parallel to the base or main end-plane, which is convenient in determining other planes,

FELDSPAR.

even in fragments; cleavage imperfect, parallel to 2d side-planes; but the two cleavages united give to fragments a cubical form. Pl. IX. figs. 32—34 represent several forms of feldspar. In fig. 32, *c* is the main end-plane, *a* and *b* the 1st and 2d side-planes; *c* and *b* are also seen in figs. 33 and 34. Beside these, fig. 33 is combined with the back oblique end-plane 2*d'*, the verticle prism *g* of the main 8-hedron, and a vertical prism $\frac{g}{3}$. Fig. 34, in addition

to *c*, *b*, *g*, and 2*d'*, has the back oblique prism *d'* of the main 8-hedron, with its back oblique end-plane *d'*. Twined crystals are frequently united on different planes, always recognised by re-entrant angles formed by planes or striæ on the surface. The same may be observed in massive feldspar.

$H = 6$. $G = 2.5$, Adularia, 2.59, Glassy, *F.*

Color white, grayish, reddish, greenish; flesh-red, green; lustre vitreous, rarely pearly; transparent, translucent; fracture conchoidal to uneven; streak white, or grayish-white.

Behavior. Fuses with difficulty on the edges to a semi-transparent, blebby glass; dissolved slowly by borax and soda to a transparent glass, the latter rarely free from bubbles; mic. salt dissolves it when pulverized, leaving a siliceous skeleton; becomes blue on the fused edges, with cobalt solution; not attacked by acids; vitrifies superficially, or may fuse in a porcelain furnace, to a translucent, bubbly glass.

Analysis. This important mineral has been frequently analyzed, and with somewhat varying results; but nearly all analyses lead to the general formula $\text{KO}, \text{SiO}_3 + \text{Al}_2\text{O}_3, 3 \text{SiO}_3$. A part of the potassa is replaced by small quantities of soda, lime and magnesia, and a part of the alumina by a little sesquioxide of iron. The following analyses show the composition of orthoclase, 1. calculated from the formula; 2. Adularia, by Berthier; 3. Siberian, green, by Abich; 4. Glassy, *F.*, from Mont d'Or, by Berthier; 5. Glassy, *F.*, from basalt near Göttingen, by Schnedermann; 6. Flesh-colored *F.*, from Lomnitz, by V. Rose, who first showed the presence of alkali; 7. a highly translucent, massive feldspar, 6 miles N. W. of Wilmington, Del., spec. grav. in piece = 2.562, in powder 2.585; 8. a bluish and smoky feldspar from Brandywine quarries of Blue rock (*Trappan*), a few miles N. E. of Wilmington, Del.; resembles glassy feldspar; spec. grav. = 2.603. Nos. 7 and 8 by Booth and Boyé, *Trans. Am. Phil. Soc.*, II. 53.

In No. 3 the 0.49 consisted of oxides of copper, iron, and manganese, the first of which is probably the cause of the green color. It will be observed from the following analyses, and from the composition of orthoclase in the tabular view of feldspathic minerals, that although potassa in general predominates, it is probably always replaced partially by soda. Abich has found 4 pr. ct. soda in a glassy feldspar; but if Schnedermann's analysis be correct, the quantity he finds, 10 pr. ct., is surprising. A large proportion of soda is characteristic of trachytic feldspars.

FELDSPAR.

FELDSPATHIC MINERALS.

	1.	2.	3.	4.	5.	6.	7.	8.
Silica	65.21	64.20	65.32	66.1	64.86	66.75	65.24	66.51
Alumina	18.13	18.40	17.89	19.8	21.46	17.50	19.02	17.67
Potassa	16.66	16.95	13.05	6.9	2.62	12.00	11.94	9.81
Soda	—	—	2.81	3.7	10.29	—	3.06	3.03
Lime	—	—	0.10	—	—	1.25	0.33	1.24
Magnesia	—	—	0.09	2.0	—	—	0.13	0.30
Oxide of Iron, &c.....	—	—	0.49	—	—	1.75	trace.	1.33
	100.	99.55	99.75	98.5	99.23	98.25	99.72	99.89

Feldspars are subject to decomposition, and found in the various stages between the transparent crystal and kaolin, or porcelain clay. It is probable that carbonic acid is an important agent in its disintegration, by acting on its alkali; but it is also true, that a portion of silicate of potassa is removed. Few clays are destitute of potassa, and in those which can be traced to feldspar, it amounts still to several pr. ct.

Varieties and Localities. *Adularia* (from Adula, a peak of St. Gothard) is usually applied to a transparent variety generally found in granite rocks, and includes *Valencianite*, *Moonstone*, presenting pearly reflections; when polished, *Sunstone*, opalescent from scales of mica. *Common feldspar* includes subtranslucent varieties, although many of those included under the name are not true feldspars. (See FELDSPATHIC MINERALS.) *Necronite* gives off a fetid odor when struck. *Murchisonite* from Dawlish and Arran, is yellowish gray. *Leelite* from Gryphytian, in Sweden, is deep flesh-red, with a waxy lustre. *Glassy-feldspar* is a more distinct variety, with a large proportion of soda, and is characteristic of trachytic rocks; the term *Ice-spar* is also given to this variety. *Amazonstone* is the green, Siberian variety. The *Aventurine* variety owes its play of light to particles of iron pyrites, and is found in other feldspathic minerals. The localities of this important constituent of rocks are very numerous. Double twin crystals are abundant around Carlsbad. Among the finer localities of crystallized feldspar are Ekaterinenburg, in Siberia; Arendal, in Norway; Warmbrunn, in Silesia; St. Gothard, Baveno, in Piedmont; Land's End; Mourne Mountains, Ireland. Glassy feldspar occurs abundantly in the trachyte of Drachenfels, on the Rhine, in the lavas of Vesuvius. In the U. S. may be enumerated Acworth, N. H.; Paris, Maine; Rossie, St. Lawrence Co., Warwick, Amity, Edenville, Orange Co., &c., N. Y.; Haddam, Middletown, &c., Conn.; Attleboro, &c., Penn. *Adularia* occurs at Parsonsfeld, Me.; Brimfield, Mass.; Haddam, Norwich, Conn.; sunstone at Lyme, Conn.; an aventurine variety at the quarries near Leiperville, Penn., and at the Brandywine quarries, Del., where the play of light is due to spangles of iron pyrites: necronite occurs at Rogers's rock, Essex Co., and at Thomson's quarry near 196th street, N. Y.

Massive feldspar is found at most of the above localities in the U. S., besides many

others. A few miles north-west of Wilmington, Del., there is a large vein of a white feldspar, masses of which are semi-transparent. Some of the disintegrating parts of the vein appear to be albite.

Use. Moonstone and amazonstone are sometimes employed as gems. Massive feldspar, when sufficiently pure, is largely used in fine pottery and porcelain, to flux the quartz and clays. The presence of much iron renders it worthless. Kaolin, or partially disintegrated feldspar, is the basis of fine pottery and porcelain. Cornish granite presents its feldspar intermediate between kaolin and the crystalline mineral, and may be viewed as the most important constituent of English pottery.

Feldspar, reduced to fine powder, and treated with sulphuric acid, has been employed for the manufacture of alum. It has also been proposed as a source of potash, and its large content of that alkali, 12 to 16 pr. ct., renders its economical extraction very desirable for the arts.

FELDSPATHIC MINERALS. *Min.* Feldspar is an essential and abundant constituent of granite, sienite, and other plutonic rocks, but many minerals have been included under the common name of feldspar, which present differing constitutions by formula, but from their general resemblance, they may constitute a special order of feldspathic minerals. Svanberg, upon examining the feldspars of Scandinavian granite, found some of them composed according to the formula $2(3\text{RO}, 4\text{SiO}_3) + 3(\text{Al}_2\text{O}_3, 4\text{SiO}_3)$, another $= 3(\text{RO}, \text{SiO}_3) + 2(\text{Al}_2\text{O}_3, 3\text{SiO}_3)$, a third $= \text{RO}, \text{SiO}_3 + \text{Al}_2\text{O}_3, 2\text{SiO}_3$, a fourth $= 6(\text{RO}, \text{SiO}_3) + 5(\text{Al}_2\text{O}_3, 2\text{SiO}_3)$. The first is labradorite, with an excess of silica, and of the silicate of alumina; the second is feldspar, with an excess of silicate of RO; the third is oligoclase; and the fourth is oligoclase, with an excess of silicate of RO. We have examined an albite from Delaware, which was composed nearly according to the formula $5(\text{RO}, \text{SiO}_3) + 6(\text{R}_2\text{O}_3, 2\text{SiO}_3)$. See *Proc. Am. Phil. Soc.* 1841, and the art. ALBITE in the present work. RO includes potassa, soda, and lime in all but the second, which has no lime.

The following table, constructed by Abich, exhibits feldspathic minerals, divided into two classes by their crystalline form, those of the triclinic system abounding in soda and lime, those of the monoclinic system chiefly characterized by potassa.

3 G

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Triclinic or Soda Group.

Name.	Authority.	Sp. Gr.	SiO ₃	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	KO	NaO	Total	Formula.
Anorthite ..	Abich...	2.763	44.12	35.12	0.70	19.02	0.56	0.25	0.27	100.04	3 RO, SiO ₃ + 3(R ₂ O ₃ , SiO ₃)
Labradorite	{ Abich . Kersten	2.714 —	53.48 52.45	26.46 29.85	1.60 1.00	9.49 11.70	1.74 0.16	0.22 0.60	4.10 3.90	98.40 99.66	2 RO, SiO ₃ + R ₂ O ₃ , SiO ₃
Andesin....	Abich...	2.733	59.60	24.28	1.58	5.77	1.08	1.08	6.53	99.92	3 RO, 2 SiO ₃ + 3(R ₂ O ₃ , 2SiO ₃)
Oligoclase .	Berzelius	2.668	63.70	23.95	0.50	2.05	—	1.20	8.11	100.16	RO, SiO ₃ + R ₂ O ₃ , 2 SiO ₃
Pericline .	Gmelin .	2.641	67.94	18.93	0.48	0.15	0.65	2.41	9.98	99.90	RO, SiO ₃ + R ₂ O ₃ , 3 SiO ₃
Potash al- bite	Abich...	2.622	70.22	17.29	0.82	2.09	0.41	3.71	5.62	100.16	
Albite	Rose	2.614	69.78	18.79	—	—	—	—	11.43	100.00	
do.	Erdmann	—	69.11	19.34	0.62	—	trace	0.65	10.98	100.70	

Monoclinic or Potassa Group.

Ryacolite ..	Rose	2.678	50.31	29.44	0.28	1.07	0.23	5.92	10.56	97.81	RO, SiO ₃ + R ₂ O ₃ , SiO ₃
Glassy feld- spar	Abich...	2.597	66.73	17.36	0.81	1.23	1.20	8.27	4.10	99.00	RO, SiO ₃ + R ₂ O ₃ , 3 SiO ₃
or	do. ...	2.553	67.87	15.72	2.41	3.16	1.40	6.68	2.86	100.10	
Soda feld- spar	do. ...	2.595	68.23	18.30	1.01	1.26	0.51	2.53	7.99	99.83	
Feldspar ...	do. ...	2.496	66.15 65.77	18.85 18.57	trace do.	trace 0.34	— 0.05	13.99 14.02	1.01 1.25	100.00 100.00	

To labradorite, by Abich, must be added 9.89 of protoxide of manganese. The anorthite analyzed was from the dolomite-boulders of Somma, but Forchhammer has found it in Iceland; labradorite, from modern lavas of Etna, and characterizes dolerite and some basalts. The formula of andesin is that of leucite, which crystallizes according to the regular system; it was formerly called pseudo-albite, and occurs in greenstone, in andesite. Oligoclase is from Scandinavian gneiss-granite. Pericline is found in veins in granite; potash albite is a characteristic constituent of the trachyte of Drachenfels. The 1st albite is calculated according to the formula; the 2d is from Brevig, in Norway. Ryacolite, in the dolomite boulders of Somma. The 1st glassy-feldspar from Epomoeo, the 2d from Somma, and the 3d from Pantellaria; it characterizes trachytic rocks. *Perz. Jahresh.* xxi. 190.

FELLINIC ACID. See BILE.

FERMENTATION. *Tech. Chem. Ger. Gährung.* On account of its bearing upon animal and vegetable physiology, its application to domestic economy and its important play in the arts, fermentation is highly deserving the minutest investigation by the chemist, more especially when we consider the present evident tendency of chemical science to extend the principle of ferments to a large number of important chemical changes. Former chemists, and indeed we may say the ancients, distinguished 4 kinds: the vinous, panary, acetous and putrefactive; but of these the acetous is hesitatingly placed under fermentative changes, while the panary combines the vinous and others. At present we distinguish the

Dextrinic,	Butyric,	{ Benzoic, Sinapic, Gaultheric.
Glucosic,	Mucous,	
Vinous,	Acetous,	
Lactic,	Putrefactive,	

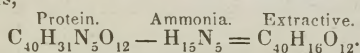
To these some chemists add others, and other chemists throw some of the above out of the class of true fermentations.

The alcoholic, which is a type of the rest, consists in the change of a saccharine solution, with the presence of yeast or ferment, resulting in the production of an alcoholic liquid. The juice of fruits ferments spontaneously, as it encloses both the ferment and sugar. To the infusion of malted grain ferment is added; but after fermentation the quantity of ferment is increased, being formed from a substance existing in the grain. We shall first consider the nature of ferment and fermentation, and then the several kinds enumerated above.

1. *Ferment.* Syn. Yeast, Leaven, Barm. *Ger.* Hefe, Gährmittel. *Fr.* Levure, Levain. The yeast which rises to the top of fermenting malt liquor (see BEER), is composed of ovoidal globules (*mycoderma cerevisia*), about $\frac{1}{2500}$ inch in diameter, the surfaces of which often have minute appendages, which are regarded by some as germs, attached to their producing cells. When fermentation is progressing, the globules move about in all directions; and if an albuminous or nitrogenous matter be in the saccharine solution, the lateral appendages become more fully developed, and after attaining a certain size separate and assume an independent existence. In beers, containing gluten or nitrogenous matter, from which the yeast is formed, the latter increases to many times the volume of what was originally introduced into the liquid. From this view it would appear to be organized and endowed with vitality, a theory which some chemists maintain. When a liquid contains an excess of ferment, the latter continues acting until all the sugar is converted into alcohol, and then loses its properties as a ferment in the same liquid

which, say the same chemists, shows its vitality, inasmuch as its existence ceases with the removal of its nourishment,—sugar. To this must be added, that all albuminous matters are readily convertible into ferment. Gluten changes to ferment by the action of air and moisture, at common temperatures. Albumen, with water and sugar, at 91° becomes a true ferment in about 3 weeks, and fermentation then proceeds, although slowly. The same takes place with casein, muscle, &c.; and when any of these is once converted into ferment, it produces a deposit of ferment which determines an ordinary rapid fermentation. It would also appear that the globules of these ferments are of the same form and dimensions as those of yeast, from whatever source derived. Add to this, that only a nitrogenous matter is capable of becoming a ferment, and among these only such as has formed part of an organized structure. These and some other facts seem to point out the organized nature and vital action of a ferment.

According to Mulder, yeast is a plant consisting of isolated cells, the tissue of which has the composition $C_{12}H_{10}O_{10}$, and therefore approximates to, without being identical with cellulose. Each vesicle encloses a protein body, which being insoluble in boiling alcohol and readily soluble in acetic acid, is neither gluten nor albumen; and is so easily altered by boiling water, that it may be regarded as superoxide of protein, $C_{40}H_{37}N_5O_{26} = C_{40}H_{31}N_5O_{12} + O_8 + 6HO$. Extracted with acetic acid, and precipitated by carbonate of ammonia, it has an analogous composition to fibrin, albumen and casein. The vesicles during fermentation are penetrated exosmotically by the protein body which immediately undergoes decomposition at a certain temperature, forming ammonia and an extractive which has not been accurately examined. Thus,



According to Mitscherlich, fermentation is effected by a vegetable, putrefaction by an animal production, and that by only one species of infusory animal. When sugar is added to a liquid containing these animals, a vegetable body, ferment, is produced; and when more sugar is added, the production of the animals ceases, and that of the ferment is increased. In the upper or common fermentation, the globules are larger, and have smaller globules branching off from them, which act as germs, to produce yeast. In the lower or Bavarian process, the ferment consists of small globules only, which grow isolated in the liquid.

Bouchardat distinguishes 3 alcoholic ferments: common beer-yeast, of larger globules with germs, which completes fermentation in a few days at from 50° to 85°, and cannot act in a strong alcoholic liquid; ferment of lees (lower ferment), of smaller globules, which acts between 50° and 55°, completes its process in 3 or 4 months even in liquids of 16 pr. ct. alcohol, and is not sensibly decomposed during that time; and black ferment, of still smaller globules, which produces fermentation

in not less than 6 months, even in a 17 pr. ct. liquid, and is not destroyed during fermentation.

On the other hand, it may be said that the peculiar organic form of the globules of yeast is no more an evidence of their vital existence, whether fungous or animal, than the semi-organized forms of amylaceous matters. If the vitating globules of yeast feed upon sugar and evolve it wholly, as carbonic acid and alcohol, they act differently from what we know of all other plants or animals. Regarding fermentation, with Liebig, as an instance of a decomposing substance, ferment, inducing the transformation of another, sugar, the former does not cease to act after the sugar has been wholly transformed, but continues decomposing, although slowly, by reason of its insolubility.

By Berzelius and others, fermentation is supposed to be produced by a catalytic force, a name given to a series of phenomena in which a compound body is decomposed by the presence or contact of another body, without receiving any thing from the latter. But a careful examination of the several phenomena classed under catalytic action, will show that very different conditions are required in different instances; and since the phenomena of fermentation are of a distinct character, they are more conveniently studied under the views set forth by Liebig.

Yeast is partially soluble in water, but it is neither the soluble nor insoluble portion which induces fermentation in a sugar solution, if oxygen be excluded. Colin has showed that it is the soluble which possesses this power, and that only when oxygen is present. When the hot infusion is decanted from the insoluble residue, and exposed to the air, it induces rapid fermentation, which it would not do previous to its exposure. The yeast disappears during fermentation, by oxidation and a transformation of its constituents. Thénard found that 100 pts. of sugar were wholly fermented by 20 pts. beer-yeast, the insoluble portion of which, after fermentation, amounted to 13·7; and that this was reduced to 10 pts. by fermenting a fresh solution of sugar. The last 16 pts. had the properties of woody fibre. When yeast is thoroughly washed, the residue loses the power of inducing fermentation, but regains it when, by exposure in a warm place, it commences again to decompose. When the quantity of ferment is insufficient, all the yeast and a corresponding amount of sugar disappear, but the excess of sugar remains in the alcoholic solution. When the yeast is in excess, a portion of it remains after all the sugar is converted, and scarcely decomposes, or very slowly; but if added to a fresh solution of sugar, induces its transformation. It appears, then, that yeast only acts when it is itself in a state of decomposition or eremacausis, through the oxidizing action of the air; and that it communicates a chemical or molecular movement to the elements of sugar, inducing their re-arrangement in other forms. Fermentation, then, is an instance of inducing affinity. Liebig.

The first cause of fermentation is heat; for

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at a certain temperature the protein compound of yeast cannot exist in solution, and its decomposition extends to the sugar. A small quantity of oxygen is absorbed at the commencement, but its absorption is rather the consequence, than the cause of the decomposition of the protein compound. *Mulder*.

Among the various causes of transformations, *Liebig* draws attention to three, as playing the most important part in fermentations: *eremacausis*, fermentation and putrefaction. *Eremacausis* (see this Art.) is the slow combustion of a body by the oxygen of the air, whereby new and simpler compounds are produced. Fermentation is the transposition of the elements of one complex compound, by the presence of a body in the act of decomposition, producing new and simpler compounds with or without the assistance of the elements of water. Putrefaction is the transposition of the atoms of two or more complex compounds, the elements of both arranging themselves mutually into new products, with or without the co-operation of the elements of water.

Eremacausis takes place when the body is simply moistened with water, or by the assistance of an alkali, or most commonly by contact with another body already in the state of decay. In this action a body absorbs oxygen, which chiefly seems to act on its hydrogen, forming water, while a portion of the carbon and oxygen remaining, separate as carbonic acid. The removal of a portion of hydrogen has induced the transposition of the remaining atoms, so that carbonic acid and other products are formed, according to their affinities. In the putrefaction of nitrogenous bodies, we have also the affinities of carbon for oxygen and nitrogen for hydrogen, thus exhibiting an analogy between *eremacausis* and putrefaction. In fact all putrefying bodies pass into a state of decay when exposed freely to the air, and all decaying matters into that of putrefaction, when air is excluded. In organic bodies destitute of nitrogen, the ultimate products of decay are carbonic acid and water; and if nitrogen be present, ammonia is formed in addition to these; but there are also other substances resulting under some circumstances, such as hydrogen or a carbohydrogen. Fresh, moist gluten evolved in 5 weeks 28 times its volume of gas, of which $\frac{3}{4}$ were carbonic acid and $\frac{1}{4}$ pure hydrogen, but no ferment was formed. (*De Saussure*.) Now hydrogen is not evolved in fermentation with yeast, and hence the transformation of gluten in a saccharine solution is of a different kind from that just noticed. It is probable that the change of gluten to the insoluble state is due to the absorption of oxygen, and that partly from water. The change produced in gluten by oxidation in a sugar solution, is transferred to the sugar which is separated into alcohol and carbonic acid; in other words, the fermentation of the sugar is a reflex action of the transformation of gluten. Other substances being usually present in these solutions, are of course more or less inductively affected by the chemical changes going forward. Thus enanthic ether and amylic alco-

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hol, etc., are generated during fermentation, and are the results of partial deoxidation. But some of these bodies being probably formed by a mutual interchange of the elements of gluten and sugar, a true process of putrefaction is going forward. *Liebig*.

Composition and behavior of ferment. Payen's proximate analysis of yeast gave in 100 pts.,

Nitrog. matter, with sulphur	62.73
Envelope of cellulose.....	29.37
Fatty matters.....	2.10
Mineral matters	5.80

100 parts of purified yeast gave, according to Dumas, Mitscherlich and Schlossberger,

	D.	M.	S.
Carbon	50.6	47.0	47.93
Hydrogen.....	7.3	6.6	6.69
Nitrogen.....	15.0	10.0	9.77
Oxygen, &c.....	27.0	36.4	35.61

Sulphur and phosphorus are included in the oxygen.

Schlossberger divided the yeast by potassa into two parts: a nitrogenous body analogous to protein and cellulose. *Mulder* gives for the composition of the envelope $C_{12}H_{10}O_{10}$, which is not cellulose; and for the enclosed body, $C_{40}H_{37}N_5O_{26}$, which is protein with O_8 and 6 HO. Mitscherlich's analysis of yeast dried at 248°, gave 7.5 to 7.6 pr. ct. ashes, which contained in 100 pts.,

	1.	2.
Phosphoric acid.....	41.8	39.5
Potassa	39.5	28.3
Phosphate of magnesia....	16.8	22.6
Phosphate of lime.....	2.3	9.7

The beer from which this yeast was taken gave 30.7 pr. ct. ashes, of the following composition:—

Phosphoric acid	20.0
Potassa	40.8
Soda	0.5
Phosphate of magnesia	0.0
Phosphate of lime.....	2.6
Silica	16.6

Yeast dried at 212°, or boiled for 4 or 5 minutes in water, does not wholly lose its fermenting power, but its energy is much weakened. An exposure during a night to a temperature of 14° or 12°, does not diminish its power. The most remarkable behavior of yeast is to sugar in solution, transforming the latter wholly into alcohol and carbonic acid. The best proportions of the solution for rapid action are 1 pt. sugar to 3 or 4 water, and 1 pt. fresh yeast to 5 pts. sugar, although 50 pts. sugar by fermentation only destroy 1 pt. yeast, calculated in the dry state. The best temperature is between 70° and 80°.

Different substances have a different action on the fermenting power of yeast. Left in contact with alcohol for 24 hours at 113°, and then evaporated, yeast produces fermentation after a day, but still feebly; if left in a strongly alcoholic liquid fermentation ceases, and the globules of yeast contract; hence it is that wines cannot be obtained by fermentation of

greater strength than 15 pr. ct. alcohol. 6 drops of oil of turpentine with 2 oz. water, $\frac{3}{4}$ oz. sugar and 15 grs. yeast, will not ferment. The mineral acids either retard or prevent fermentation. Sulphuric, sulphurous, muriatic and nitric, 6 drops of each, with the above proportion of sugar, water and yeast, prevent fermentation; phosphoric and arsenious retard it. The same proportions of ingredients being used, 5 or 10 drops of acetic acid (of 10°) and of a strong solution of lactic acid, do not affect fermentation, 20 to 80 drops destroy it; tartaric and citric oppose, but do not hinder it; oxalic and prussic wholly prevent it; tannic appears to have no influence. The alkalies, free or carbonated, hinder, and may prevent it; but it commences as soon as they are neutralized, and the liquid has a slight excess of acid; their presence tends to form more amylic alcohol, where its sources are present. Strychnin and morphin retard the process by their alkalinity; for, when neutralized, it progresses as before; some alkaloids are without any action. Cream of tartar, acetate of potassa and Glauber's salt have rather a favorable, than injurious action. Sulphuretted hydrogen, the sulphites and soluble sulphurets, oxide of mercury and probably other oxides in a hydrated state, prevent fermentation; oxide of lead seems to be entirely innocuous. Calomel has no influence; alum and sugar of lead retard it, and verdigris and corrosive sublimate prevent it altogether. (*Quévenne*.) $\frac{1}{150000}$ of oil of vitriol is sufficient to arrest fermentation, which does not commence until the proportion is reduced to $\frac{1}{250000}$. It appears that the smallest quantities retard it, for, with $\frac{1}{390000}$, only half as much carbonic acid is given off as by a normal fermentation without acid, in the same time; and while the latter is completed in 48 hours, the former is not finished in 8 days. It not only retards the alcoholic change, but produces the viscous fermentation. *Calvert, Journ. de Phar. et de Ch. ix. 92.*

Yeast dissolves in chlorohydric acid, imparting a red color to it, like protein compounds. By successive treatment with water, alcohol and ether, there are obtained from it lactic acid, phosphate of potassa, fatty matters, and a yellow oil of an aromatic odor and taste, soluble in strong sulphuric acid, with a cherry-red color; the remainder consists of globules similar to those in fresh yeast, but of less diameter, and is no longer capable of producing fermentation. Fresh yeast ground up with an equal weight of white sugar is soon converted into an oily liquid, in which, as well as in molasses, it will keep for years unimpaired.

2. *Fermentation in general.* Although the various kinds of fermentation agree in certain points, yet they differ so much in their results, that some chemists still adhere to the older divisions of vinous, acetous and putrid. Their agreements and differences follow, but let it be borne in mind that but few of them have been minutely studied, in consequence, no doubt, of the great difficulties attending the investigation.

Contact. The contact of a nitrogenous organic body, the ferment, is necessary to pro-

duce fermentation in a substance contained in an aqueous solution; and it is probable that the ferment must be brought into a state of change or decay, before it performs its functions; for it is found in such a state where carefully examined, as instanced by yeast, diastase, emulsin, myrosin, &c. But it would appear that the ferment in different stages of decomposition, containing, therefore, different successive compounds, determines different kinds of fermentation; for, while fresh diastase will produce the dextrin and glucosic changes, when exposed for some days to a moist air, it produces the lactic transformation.

Water. It will be observed that water is essential to fermentation, not merely as the medium of chemical action, but by its sometimes taking part in the resulting chemical changes. Thus, while diastase determines a mere molecular action on starch, converting it into dextrine of the same composition, it forces the dextrine to assume the elements of water while passing into glucose. From the development of hydrogen in the putrefaction of gluten (see above), water is evidently decomposed; and we know that putrefaction in general is a powerfully deoxidizing process, abstracting oxygen from water, where the supply of this element from the air or the solids present is insufficient.

Relative quantity. The catalytic phenomena of fermentation are characterized by the relation of quantity between the ferment and the fermented. A very small amount of emulsin will convert a large amount of amygdalin into oil of bitter almonds, prussic acid, &c. One part of dry yeast will catalyze 50 pts. sugar into alcohol and carbonic acid. One part diastase will convert 2000 pts. starch into dextrine and glucose.

Temperature. A more or less elevated temperature is generally required to produce fermentation, but the different kinds take place at different temperatures. We may ascribe this development of heat to the eremacausis, or slow combustion of the ferment. The viscous fermentation takes place between 40° and 60°, although it may occur under higher degrees of heat. The fermentation of Bavarian beer cannot pass beyond 50°; the vinous is most perfect between 70° and 80°; the benzoic and acetic take place at about 100°, although the former will admit of a lower temperature. The amylic probably demands a still higher heat; and we may ascribe the formation of wood-spirit (amylic alcohol) to a catalytic action taking place at a very elevated temperature, as in the dry distillation of wood.

Prevention of Fermentation. In general, the same circumstances and substances have a similar effect in retarding or wholly preventing fermentation; many of the experiments above given on the behavior of yeast being applicable to other fermentations. The common antiseptics have the property of retarding or preventing them. The oxides, metallic salts and some organic bodies possessing this property, probably unite chemically with ferments, rendering them insoluble and inert.

FERMENTATION.

In other cases, we may ascribe it to a counter catalytic action.

Resultants. It is mainly in the resulting compounds, and the changes occurring during fermentation, as far as they are known, that a dissimilarity exists between different kinds of fermentation. In the dextrinic, starch merely undergoes a molecular change, without a change of ultimate composition; in the glucosic, dextrin assumes the elements of water; in the lactic, if the acid be formed from lactine, it loses the elements of water. The acetous change consists in the absorption of oxygen by alcohol, making a true oxidation; in the butyric and amylic, there is a deoxidation. But in some cases, the operations are wholly or in part of the putrefactive character, according to the above view of putrefaction, the elements of ferment and fermented mutually arranging themselves into new groupings; thus lactic acid is almost always one of the products of the putrefaction of animal matters; in the spontaneous fermentation of the juice of beet-roots or parsnips, at 95° to 104°, beside ammoniacal products, lactic acid, mannite and mucous matter are formed, while sugar and ferment have both disappeared. In the benzoic transformation, amygdalin is supposed to be resolved into oil of bitter almonds, prussic and formic acids, sugar and water, without union with the ferment.

It must be acknowledged that much remains for thorough chemical investigation of the ferment, the fermented, the intermediate changes and their total resultants. Hitherto, the chemist has confined himself too much to an investigation of fermentation taking place in complex bodies, especially in the ferments. We know in most cases the exact composition of the body to be catalyzed, starch, sugar, amygdalin and others; but the ferments may be complex bodies, whose proximate constituents are unknown to us. Even in the transformation of sugar, we know only the beginning and the end; that it is finally resolved into alcohol and carbonic acid, without knowing the intermediate changes which it may possibly suffer. The subject can only be rendered clear by a preparatory analytic investigation of ferments, and a careful study of the transformations of their separated constituents, under the various circumstances of oxidation and deoxidation, alkaline and acid reaction, in presence of bodies to be fermented at different temperatures, and in presence of each other under these conditions.

KINDS OF FERMENTATION.

Although we shall here regard the changes as distinct from each other, it is highly probable that many of them are consecutive; for the experiments of Boutron and Fremy have shown that the first action of the ferment in malt is the conversion of the starch into glucose by diastase; that it next assumes the character of the lactic ferment, converting a portion of the sugar into lactic acid, as shown by the acidity of the liquor. The liquid then becomes turbid, depositing a sediment, and the alcoholic fermentation takes place. That the sediment is the cause of the alcoholic

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change, is shown by filtering the liquid when the alcoholic fermentation ceases. Besides these successive changes under the same conditions, a variation of conditions may produce very different results; for, while sugar under the action of yeast is converted into alcohol and carbonic acid, with the presence of putrefying white cheese it produces butyric acid, with gluten or rennet it may generate mucous matter and mannite, and in the juices of the beet-root, &c., fermenting spontaneously at 85° to 100°, it produces lactic acid, mucose and mannite. According to Bensch, lactic acid is first formed, and then passes into butyric.

1. *Dextrinic and Glucosic Fermentation.* Starch is so rapidly converted into glucose by the action of diastase or malt, that it requires some care to observe the intermediate formation of dextrin (see DEXTRIN and DIASTASE). The change of starch into dextrin is only molecular, both substances having the same composition. The conversion of dextrin into glucose or starch-sugar, consists in the assumption of the elements of water; thus, $C_{12}H_{10}O_{10} + 2HO = C_{12}H_{12}O_{12}$. There is generally a tendency to form a portion of lactic acid at the same time. Although this change takes place slowly at common temperatures, yet its action is most energetic between 120° and 140°. The same kind of fermentation takes place in malting barley, and in the germination of other seeds; a small amount of diastase or albuminous matter in the seed converts the fecula into dextrin and glucose. So powerful is the action of pure diastase, that 1 pt. of it is said to convert 2000 pts. starch into glucose.

2. *Vinous or Alcoholic Fermentation.* The various kinds of sugar give rise to the formation of alcohol in presence of a ferment, a certain quantity of water, and at the temperature of from 40° to 80°. The ordinary rapid fermentation takes place usually between 70° and 80°; that of common ales and beers between 55° and 65°; the slower process in Bavarian beer and some wines, between 40° and 50°.

Glucose is transformed by fermentation into 2 eq. alcohol and 4 eq. carbonic acid; thus, $C_{12}H_{12}O_{12} = 2(C_4H_6O_2) + 4CO_2$. No account is taken, in this change, of the 2 eq. water in crystallized glucose. A solution of glucose polarizes light to the right, and continues to do so during fermentation. A solution of fruit-sugar, $C_{12}H_{12}O_{12}$, polarizes to the left, and likewise continues to do the same during the same change. A solution of cane-sugar polarizes to the right, but by the action of ferment soon polarizes to the left, and then acts like fruit-sugar. A solution of molasses-sugar does not polarize, and remains without polarizing power during fermentation. Dextrin, lactic and cane-sugar are converted into glucose before fermentation. (*Mitscherlich and Biot.*) The above formula is therefore adapted to all vinous fermentations; but the last three substances previously take up the elements of water, and should therefore yield a larger amount of alcohol and carbonic acid than the sum of those elements in the original sub-

stance; and in fact it is found by experiment, that 100 pts. cane-sugar yield 103 pts. alcohol and carbonic acid together. (*Liebig.*) It was stated that lactin assumes water, although its composition is $C_{24}H_{24}O_{24}$, or exactly that of glucose; but the formula of anhydrous lactin is $C_{24}H_{19}O_{19}$, whence it must take up 5 eq. water to form 2 eq. glucose. In general, and even in many nice experiments, the amounts of alcohol and carbonic acid fall several pr. ct. short of the amount of cane-sugar, which is to be ascribed to the formation of lactic acid, ammonia, and other products, partly due to a transformation of sugar, partly to putrefaction and eremacausis.

There are several modifications under which the vinous fermentation presents itself to us: *a*, where yeast acts upon a solution of sugar, or a substance transformable into sugar; *b*, where it is made to act on a solution of sugar containing also glutenous matter, by which more yeast is generated, as in beers; *c*, where yeast does not exist ready formed, but requires the action of air to generate it, saccharine matter being also present, as in the juice of grapes and other fruits; *d*, the high and low fermentations; *e*, the secondary products due to various conditions and foreign substances; *f*, the panary fermentation.

a. The conditions of fermentation have been already stated above, under the behavior of ferment. When yeast is added to a solution of sugar in due proportions, and examined by the microscope, carbonic acid is observed to be developed around a globule of yeast, to increase in size until the combined specific weight of the globule and gas is less than that of the liquid, when they rise together to the top, and the gas bubble bursting, the yeast again falls. Whence it would seem as if the transformation of sugar took place in or upon the globules of yeast, by means of its organized structure; an inference confirmed by *Ludersdorf*, who found that yeast, triturated so as to destroy its structure, ceased to produce the alcoholic fermentation. If these observations be true, they do not subvert the chemical views of *Liebig*, set forth more fully above, under ferment. Whatever views may be adopted, the facts are, that with a suitable mixture of well-prepared yeast, pure sugar and water, the clear liquid becomes turbid from the evolution of carbonic acid, and its circulating power over the globules of yeast; and when the fermentation is complete, the liquid becomes clear. It now contains alcohol in place of sugar, and probably always a little lactic acid and ammonia. Alcohol contracts the globules of yeast, rendering it inert; and hence when a liquid attains to a strength of 15 pr. ct. alcohol, fermentation ceases. Even this strength is rarely attained; and to those liquids which contain more alcohol, a distilled liquor has been added.

b. Under the Art. BEER, the practical details of its fermentation are fully described. This fermentation differs from the preceding chiefly in the presence of gluten in the solution and in an increase of yeast, whereas in the former case the yeast was destroyed, or converted into woody fibre. Oxygen is absorbed during the

fermentation, the gluten rendered insoluble, precipitated as yeast, and carried to the top of the liquid by the buoyant power of carbonic acid. While one part of yeast is producing the transformation of sugar and is itself transformed, it induces the eremacausis of the soluble gluten, by which it is converted into insoluble yeast. The quantity of yeast thus generated, is variously stated to be from 7 to 30 times as great as that originally introduced into the liquid. During the ordinary fermentation of beer the temperature rises from 9° to 14° higher than it had been, which is due to the low combustion of the gluten. In most beers a portion of sugar and gluten still remain unchanged, and hence their aptitude to become acidified or spoiled, by subsequent and different kinds of transformations. If a beer fermented, but not completely so, at a comparatively low temperature, is afterwards exposed to a higher temperature and to the air, a rapid fermentation is produced, which, by its raising the temperature still higher, tends to the eremacausis of alcohol and the production of acetic acid. The difference between this ordinary fermentation and that taking place at a lower temperature, will be given below.

c. In the fermentation of the juice of fruits, no ferment is added; but it contains glutenous matter adapted to form yeast; and the process therefore differs from the preceding mainly in the spontaneous formation of yeast, by the oxidizing action of the air. The juice of grapes, expressed, apart from the air, does not ferment; but when air or oxygen is admitted, fermentation commences. *Gay-Lussac.*

d. The temperature during fermentation exercises an important influence on the liquid product of fermentation. The juice of beetroots fermenting spontaneously at 85° to 95° , yields no alcohol, but in place of it lactic acid, mannite and mucose. In the ordinary fermentation, the temperature is between 55° and 80° , and the generated yeast rises to the top of the liquid. In the fermentation of wort at a temperature of 40° and 50° , as in the manufacture of Bavarian beer, if common yeast be added, a gradual and quiet change takes place, and yeast is deposited at the bottom of the containing vessel. If this precipitated yeast be employed several successive times for fermentation at the same temperature, it no longer produces common fermentation even at 50° . It is different in appearance from common yeast, being a fine, viscous slime. The time required for this fermentation is from 3 to 6 weeks. The main result is the same as usual, alcohol and carbonic acid being generated, but the latter rises in very minute bubbles from the liquid. In both high and low fermentation oxygen is absorbed, but in the former process it is absorbed more rapidly, producing a higher temperature, which together with the greater activity of chemical force, tends to resolve a portion of sugar into other products than alcohol and carbonic acid. It is deoxidized, and hence the accidental products of butyric and enanthic acids, amylic alcohol, &c. In the low fermentation, by reason of the lowness of temperature, together

with a feeble chemical force, the gluten decays slowly, and spends its catalytic action on the sugar in only one kind of transformation, converting it wholly into carbonic acid and alcohol, while the gluten goes on decaying until it is wholly precipitated. It probably undergoes putrefaction in both cases, but the nature of this change varies with the temperature, although in both it transposes the elements of sugar in the same manner. This view is confirmed by increasing the temperature of fermentation, as in the spontaneous change of beet-root juice above noticed, where alcohol is not at all generated. The low temperature and weak chemical force combined, tending only to oxidize and precipitate all the gluten, while all the sugar is converted into alcohol and carbonic acid, such a fermented liquor will be somewhat richer in alcohol, and have no tendency to spoil or acetify when once drawn off from the yeast. Hence Bavarian beer is a little more alcoholic than ordinary malt liquors, and not liable to become acid by free exposure to the air. The finer qualities of English malt liquors are improved by keeping them for several years in close vessels to ripen, during which the greater part of the gluten is rendered insoluble by very slowly absorbing oxygen, without disturbing other chemical forces in the liquid. Besides acetification, to which those liquids are liable which contain gluten, they are sometimes observed to undergo a viscous change, which is prevented by precipitating the gluten by tannin.

e. We have just seen that a higher temperature will catalyze a portion of sugar differently from a lower, and generate other products; but the presence of foreign ingredients is the most common source of secondary products. Whiskeys obtained from grain and potatoes contain fousel oils, which impart to them a peculiar odor and taste, and are derived from other substances than the ferment or sugar. The oil from potatoes is chiefly amylic alcohol; that from corn consists principally of an acid identical in composition with enanthic acid, but different in its properties. The liquor obtained from potato-starch, or from partially putrefied potatoes, is free from fousel oil, from which its presence in potato-whiskey is ascribed to the cellular tissue of the root. There is no doubt that enanthic ether is produced in wines during fermentation, and probably by the presence of tartaric acid, for the Rhenish wines which contain larger quantities of this acid, are distinguished for their bouquet, and those containing the largest amount of this acid have the strongest perfume. The acid of this ether resembles a fat acid, and the ethers of such acids are only made in the presence of a very soluble acid stronger than the acetic. The absence of such acid in liquor from grain, produces an acid similar to the enanthic, but not its ether; and in the liquor from the potato, it is found that the amount of amylic alcohol obtained is greater if the liquid be slightly alkaline. These facts seem to show the influence of foreign substances in producing various compounds in fermented liquids. (*Liebig.*) In the distil-

lation of liquors from Indian corn in the western states, very large quantities of oil are obtained and applied to practical purposes, but of its chemical nature we are ignorant. The quantity of such oil is not surprising, when we consider the complex constitution of maize, to which article refer.

f. Panary Fermentation. This has been improperly considered a distinct variety of fermentation, but in the main it is the alcoholic, under the peculiar condition of the presence of a small quantity of water. The practical details are given under the art. *BREAD*. Wheat flour contains about 69 pr. ct. starch, 11 gluten, 5 glucose, and 4 dextrin, the balance being water and salts. The small amount of water introduced is sufficient to dissolve gluten, dextrin, and glucose, which are brought into intimate mixture, and exposed to the action of the air and the leaven by working the paste. When the mixture of flour, water, and leaven, or yeast, is exposed in a warm place, it begins to puff up from the alcoholic fermentation and escape of carbonic acid, part of which is retained by the toughness of the dough. At a proper time, it is heated in an oven, whereby the progress of fermentation is arrested, the dough puffed up, and rendered porous by the expansion of the carbonic acid retained in it, and by the bursting of the amylaceous particles, and the whole made to adhere into a uniform mass. The quantity of sugar fermented, and hence the quantity of alcohol generated is so small, that the latter almost escapes detection, even when assayed on a large scale.

3. Lactic Fermentation. The same substances which undergo the alcoholic, may also produce the lactic change, and in presence of ordinary ferment. Sugar, dextrin, lactin, and glucose are all fermentible into lactic acid, but the three former probably change into glucose before they are farther transformed. Yeast must undergo a peculiar metamorphosis adapting it to this fermentation, for caseous and other nitrogenous matters, less inclined to produce the alcoholic, are better adapted to the lactic change. Casein and diastase are especially energetic. Freshly prepared diastase, which produces dextrin and glucose from starch, must be exposed to moist air for some days, in order to convert any of the above substances into lactic acid. The formula of lactin being $C_{24}H_{24}O_{24}$, or rather $C_{24}H_{19}O_{19} + 5HO$, and that of lactic acid being $C_6H_6O_6 = C_6H_4O_4 + 2HO$; the former is fourfold by a molecular division, and 3 eq. of water taken from its anhydrous base are added to the combined water of 4 eq. of the acid, thus $C_{24}H_{19}O_{19} + 5HO = C_{24}H_{16}O_{16} + 8HO = 4(C_6H_4O_4 + 2HO)$. If the lactic acid be formed from glucose, the change is similar. One eq. glucose $= C_{12}H_{11}O_{11} + HO$ throws the elements of 3 eq. water to the hydrated water, making $C_{12}H_8O_8 + 4HO$, which is equal to 2 eq. lactic acid, $2(C_6H_4O_4 + 2HO)$. To obtain this acid in quantity, malt is moistened with water, exposed to the air for some days at 75° to 85° , and saturated with lime; the lactate of lime may be purified from solution in alcohol. (*Boutron and Fremy.*) This

fermentation takes place also in milk, which is suffered to sour. By the action of casein oxidized by the air, a portion of lactic is converted into lactic acid, which by its reaction coagulates the casein, and prevents the farther development of the acid, but if chalk or soda be added, and the liquid stirred from time to time, the latter is kept neutral, and lactic acid continues to form as long as any lactic is present. Even then lactic may be added, and the fermentation kept up. The proportions employed by Pelouze and Gelis are a solution of starch-sugar of 8° or 10° Beaumé, chalk equal to half, and casein or gluten equal to $\frac{1}{10}$ th (calculated dry) of the sugar employed. The cheese or gluten may be employed in almost any state. The sugar changes first into a mucous substance, without mannite, then to lactic, and, finally, to butyric acid. (Pelouze and Gelis.) The same circumstances which oppose the alcoholic, prevent or retard the lactic fermentation. The warm temperature of summer rendering milk apt to turn sour by the lactic fermentation, the evil is remedied by keeping it excluded wholly from the air, or by boiling it a few moments every day, which may preserve it for months. M. Gelis observed that towards the close of the lactic there appeared the

4. *Butyric Fermentation*, the same substances, ferment and fermentable, being present. But it is evident, that the ferment must again have changed character, been otherwise transformed, and that by an oxidation, as we may infer from analogy. It will at all events be evident, from a consideration of the formula of lactic and butyric acids, that the lactic has been deoxidized. The formula of lactic acid is $C_6H_8O_6$, of butyric $C_6H_8O_4$, both in their hydrated state; therefore 4 eq. lactic acid = $C_{24}H_{32}O_{24}$, are equal to 3 eq. butyric = $C_{24}H_{24}O_{12}$ together with O_{12} . The lactic loses half its oxygen in passing into the butyric acid. The oxygen requisite in fermentation is first drawn from the air, but after some time it is abstracted from the substances in solution. The same remarks hold good if the butyric acid be produced from glucose. But the change noticed is not a simple deoxidation, for the true formula for 4 eq. lactic acid is $C_{24}H_{16}O_{16} + 8HO$, and that for 3 eq. butyric is $C_{24}H_{21}O_9 + 3HO$, from which it is evident the 4 eq. lactic acid assume 5 eq. of their hydrate-water, making $C_{24}H_{21}O_{21} + 3HO$, and then lose 12 eq. oxygen in order to form 3 eq. butyric acid. The action is similar to the lactic change from glucose without deoxidation. As in the formation of lactic acid, chalk or soda may be employed for neutralizing the liquid and continuing the fermentation. The formation of butyric acid from lactic presents us with an interesting relation between these substances which are found together in milk. Many other instances of the butyric fermentation have been observed. Scharling observed that potato-mass, from which starch had been obtained, yielded butyric acid by fermentation. Schubert observed the same of boiled and mashed potatoes, mixed with cheese and water. Marchand noticed a large amount of butyric acid in the liquid of pickled cucumbers.

Larocque observed that several mucilaginous plants, the root of althea, the bulb of lily, flaxseed, &c., when mixed with a certain quantity of water and chalk, and suffered to evaporate spontaneously, fermented and produced butyric acid.

5. *Mucous or Viscous Fermentation*. This change has been chiefly observed in liquids containing the same ferment and fermentable substances as the preceding changes. A mucilaginous matter gradually forms in these liquids under some circumstances which have not been studied. Desfosse observed that by boiling yeast or gluten in water, filtering, dissolving sugar in the liquid, and exposing it in a warm place, a mucilage is formed, while carbonic acid and hydrogen gases are disengaged. Baudrimont did not observe the slightest evolution of gas. Peligot believes that it generates its peculiar ferment, resembling yeast under the microscope, and that when once developed, it is best adapted to produce the viscous fermentation at a proper temperature. But, from some experiments, it appears to weigh more than the sugar from which it is formed, from which it is inferred that the viscous change assumes the elements of water. According to Pelouze, it has the composition of anhydrous sugar; and if so, it relinquishes water, since it must be itself hydrous. Fremy observed that rennet, in a saccharine solution, produces a substance identical with mucose, while the rennet was not altered in weight. The mucous change is often observed in white wines, probably due to remaining gluten, and is prevented by adding tannin, which precipitates the ferment. It is separated from red wines by their remaining in contact with vine-branches for a length of time. Many of the substances detrimental to the alcoholic are also preventives of the mucous fermentation. Mannite is sometimes formed during, or rather towards the close of the mucous change, and as it contains more hydrogen than to form water with all its oxygen, a deoxidation has taken place. Thus, if from 2 eq. glucose, $C_{24}H_{24}O_{24}$, we take away 2 eq. oxygen, the remainder has the composition of 1 eq. woody fibre, mucose (?), and 2 eq. mannite, $C_{24}H_{24}O_{22} = C_{12}H_{10}O_{10} + 2(C_6H_6O_6)$. The mucous transformation has been little studied, and there are probably other products which have escaped attention. A mucous change is often observed in liquids of tanneries, and in the low putrefaction of hides, but it has received still less attention.

6. *Acetous Fermentation*. It will be observed, by reference to the art. ACETIC ACID, that the practical details, and the theory, in part, are given under §§ 1 and 2. The resulting change is the abstraction of 2 eq. hydrogen from alcohol, and the addition of 2 eq. oxygen, but it is evident that something more is required than mere contact with the air. A pure alcoholic liquid will not acetify, and we have seen above, that while Bavarian beer is not subject to this change, other beers are liable to become acid. The distinguishing features between these beers is that the latter contain glutinous matter, which has been removed

from the former. There is as much tendency in the alcohol to absorb oxygen in the one case as in the other. The greater power which the latter possess of absorbing oxygen and acetifying is therefore due to the presence of the gluten. An alcoholic liquid may drip over the interminable surfaces of fresh shavings, and be therefore in a very favourable condition for acetifying, without undergoing this change; but when the shavings have been imbued with fermenting and putrefying acetous liquid, pure dilute spirit passing through them will readily become acetic acid. It is, then, evident, that a peculiar acetous ferment is required, a glutinous body in a peculiar metamorphosed state, to give the alcohol sufficient power to assume oxygen from the air. One eq. alcohol absorbs 2 eq. oxygen, which combining with 2 eq. hydrogen to form water, constitutes a low combustion. More oxygen is not at first absorbed, because the elements, after the removal of the hydrogen, are in such proportion and equipoise as to constitute another body, aldehyde. But the forces in action are such that the change does not cease with the formation of aldehyde, which absorbs 2 eq. more of oxygen to form a still more stable compound, acetic acid.

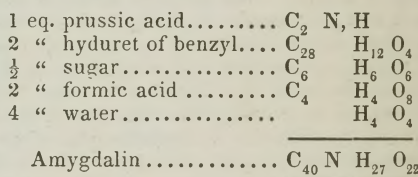
It becomes a question, on the fungous theory, whether the plant constituting the mother of vinegar may not act as the ferment to vinegar. The investigations of Mulder on its formation are of too deep an interest to be omitted, inasmuch as they show the return of acetic acid, a nearly final product of the series of alcoholic fermentations to an organized condition. Mother of vinegar is a fungous plant, or very simple organized form, the *Mycoderma cerevisia*, found in pure wine and beer vinegars, as well as in others, excepting wood vinegar. The principal constituent of wine vinegars is acetic acid and water, but they also contain small quantities of salts, sugar, gum, extractive, and especially protein, which is derived from the albumen of grapes and kept in solution by acetic acid. On removing the mother as fast as it forms, the strength of the vinegar continually diminishes, till nothing but water remains, so that acetic acid and protein constitute the food of the plant. The whole plant, freed from acetic acid, has always the same composition, and may be expressed by the formula $C_{136}H_{115}N_5O_{96}$. The membrane enclosing the protein, after being freed from the latter by potash, and boiling in hydrated acetic acid, is white, and has the composition of cellulose, $C_{24}H_{21}O_{21}$. If from the whole plant we extract 1 eq. protein, there remain 4 eq. cellulose; $C_{136}H_{115}N_5O_{96} = C_{40}H_{31}N_5O_{12} + 4C_{24}H_{21}O_{21}$. The protein then has passed from the soluble state of albumen, as contained in the grape and vinegar, into an insoluble and organized form, which has been enclosed by a cellulose membrane derived from the acetic acid. In fact, $6C_4H_3O_3 + 3HO = C_{24}H_{21}O_{21}$, or 6 eq. acetic acid take up 3 eq. HO to form 1 eq. cellulose, or 6 eq. hydrate of acetic acid lose 3 eq. water to effect the same change.

The acetous fermentation differs in some respects from all others, but this may be be-

cause it has been more minutely studied; and if we admit the butyric, where there is a de-oxidation, other things being analogous, we may freely admit the acetous to be a true fermentation.

This closes the series of transformations of starch and other neutral hydrates of carbon, by the presence of certain nitrogenous substances undergoing a change or putrefaction. In one series we have starch, dextrin, glucose (lactic acid?), alcohol; in another, starch, dextrin, glucose, lactic and butyric acids; and in a third, starch, dextrin, glucose, mucose, and mannite. The transformations which follow are those in which certain volatile oils are generated, and the putrefactive fermentation.

7. *Benzoic Fermentation.* Bitter almonds, well pressed, to rid them of their fat oil, treated with water and warmed, develop the odor of prussic acid, and by distillation yield the volatile oil of bitter almonds, other substances being formed at the same time. These products did not exist in the almonds, and have been formed by the contact of two substances in the presence of water. When a peculiar albuminous principle, emulsin, and another neutral body, amygdalin, are separately obtained from bitter almonds, and then brought together with water and heated, the same reaction takes place, as noticed above, with the bitter almonds themselves. The reaction is produced by the contact of the ferment, emulsin, with amygdalin, and the latter is transformed into cyanohydric acid, hyduret of benzyl, formic acid, sugar, and water, as shown by the following formula:



Dumas considers the reactions as successive, that 2 eq. hyduret of benzyl, $C_{28}H_{12}O_4$, and 1 eq. ammonia, NH_3 , are first formed, leaving a body $C_{12}H_{12}O_{18}$, which last, by another action of the ferment, is resolved into $\frac{1}{2}$ eq. sugar, $C_6H_6O_6$, and 3 eq. formic acid, $C_6H_6O_{12}$; that 1 eq. of formic acid unites with the eq. ammonia first produced, forming prussic acid and water, $C_2H_2O_4 + NH_3 = C_2NH + 4HO$. This interesting reaction, by which a volatile oil and other bodies, not previously existing in a plant, are produced by a fermentative action, was fully developed by Wöhler and Liebig in their masterly investigation of the benzylic series; and has led to the belief in other analogous transformations, some of which have been realized, and others doubtless will be discovered.

8. *Sinapic Fermentation.* The odorous and pungent oil of mustard exists ready formed in the leaves of *Cochlearia officinalis*, and in the roots of horse-radish and alliaria, but no trace of it is perceived in dry black mustard-seed. When the flour of this seed is moistened with water and warmed, the odor and taste be-

come very pungent, from the development of the oil. It was inferred by comparison with the benzoic transformation, that a similar change takes place in the flour of black mustard, which has been verified by separating the ferment and fermentable bodies, and testing their mutual action; but the full nature of the change remains to be developed. The ferment termed myrosin, is analogous to albumen and emulsin, although these bodies cannot replace it in the production of oil of mustard. The fermentable body termed myronate of potassa, has a complex constitution, containing carbon, hydrogen, nitrogen, sulphur, and oxygen. When these two bodies, separated from the seed, are brought together in solution and warmed, the oil of mustard is developed, the liquid becomes cloudy, and deposits a substance in minute globules, thus resembling the fermentation of beer. The liquid becomes acid, but has not been fully investigated. Myrosin being coagulable by acids, alcohol, and heat, will not then produce the essential oil, but if suffered to remain some time in contact with water its peculiar action is restored. This fermentation presents the peculiar phenomenon of the presence of a base with the myronic acid to assist in producing its transformation, but the action once established, more acid is generated than is sufficient to neutralize the alkali.

White mustard seed containing myrosin, but little or no myronate, is not adapted to form oil of mustard, as is known from experience; but when digested with cold water, it furnishes a pungent substance and rhodanhydric acid (sulphocyanhydric). The development of this acid shows a striking analogy between this and the benzoic change, in which cyanhydric is produced. White mustard contains a principle, sinapisin, but its transformations have not been specially studied.

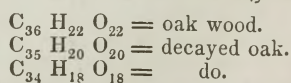
9. *Gaultheric Fermentation.* The oil of winter-green, of a highly aromatic and agreeable odor, is obtained from the *Gaultheria procumbens* by distillation. Procter proved its relation to the salicyl series, and Cahours showed that the greater part of the oil was salicylate of methel. Procter obtained a similar oil by distilling birch-bark, and observing that the dry bark did not indicate the presence of the oil, inferred that it might be generated in a manner similar to oil of bitter almonds. He obtained a substance, gaultherin, from the bark, whose reactions with acids generated the oil, and with alkalis gaultheric acid. When gaultherin is thoroughly extracted from the bark, the latter ceases to produce the oil, but the odor of the oil appears on mixing gaultherin with it. It thus exhibits a close analogy with amygdalin; and although it is highly probable that a substance corresponding to emulsin exists in the bark, it has not yet been isolated.

10. Other fermentations probably exist analogous to the preceding, but they have received little attention. Salicin, found in willow and poplar barks is transformed by emulsin into saligenin and glucose, by assuming 2 eq. water; salagenin, by dilute acid, into saliretin by the abstraction of 1 eq. water; sali-

genin, by oxidizing agents, into oil of spiræa, and then into salicylic acid. The plant, *Centaurium minoris*, is destitute of odor, but when placed in water, at a slightly elevated temperature, it emits an agreeable odor, and yields by distillation a very volatile oil. The fresh leaves of tobacco are inodorous, and yield by distillation a white, crystallized, inodorous substance, nicotianin; but when moistened with water and kept warm, oxygen is absorbed, fermentation takes place, and an oily, odorous product, nicotin, is now obtainable by distillation.

11. *Putrefactive Fermentation.* It has been stated that putrefaction differs from fermentation, in being the transformation of several complex organic substances, their elements mutually arranging themselves into new combinations. When mixed organic bodies are exposed to air and moisture above 32°, they undergo a decomposition, resolving themselves into new and simpler forms, and gases, usually offensive, are evolved. The ultimate products of putrefaction are carbonic acid and water; where nitrogen is also present, ammonia; and where sulphur, sulphuretted hydrogen. The proximate principles successively developed by intermediate changes have not been investigated, but we know that lactic acid is almost always formed. That moisture is necessary, is shown by many facts in the preservation of food, and by the dried white mummies in the blown sands of Arabia. The presence of air is necessary for the commencement, if not always for the continuance of putrefaction. If a substance perfectly fresh be freed, and kept free from air, it may be kept unchanged for an indefinite period of time. A temperature of 212° is sufficient to arrest putrefaction; for milk boiled once each day has been kept for months. Appert's method of preserving food depends on these principles. It is brought to 212° in the vessel designed to hold it, which is then closed, and having been opened after years, the food is found to be unaltered. The oxygen of the air present in the vessel combines with the food at a temperature which precludes fermentation, and nitrogen only remaining when the vessel is sealed, no farther change can take place.

Wood is subject to decay and putrefaction when exposed to air and moisture, the resulting changes differing according to the more or less free access of air and moisture. Sausure proved that 240 pts. sawdust converted 10 cubic inches oxygen into the same volume of carbonic acid, containing 3 pts. of carbon, while the sawdust lost 15 pts. by weight, 12 of which must therefore have been water. It is probable that the oxygen of the air unites with the hydrogen of the wood, forming water, and that the carbonic acid is partly due to its elimination from the elements of the wood. The following analyses show the change suffered by oak wood in different stages of decay.



The quantity of carbon increases from 52½

pr. ct. to 54 and 56; and for every 2 eq. of hydrogen oxidized, 1 eq. carbon and 2 eq. oxygen are set free. There can be no doubt that the albuminous matters present in wood hasten its decay, and first induce its absorption of oxygen by their oxidation. Where air is more or less excluded, and moisture present, the changes are somewhat different. When moistened sawdust is placed in a close vessel, carbonic acid is evolved as before, but now a putrefaction takes place. White mouldered oak, taken from the interior of the trunk of an oak, dried at 212° , gave the formula $C_{33}H_{27}O_{24}$, which, compared with dry sound wood, seems to show that 5 eq. water and 3 eq. oxygen (partly from the air) have been absorbed, and 3 eq. carbonic acid set free. Thus, $C_{36}H_{22}O_{22} + 5HO + O_3 - 3CO_2 = C_{33}H_{27}O_{24}$. White mouldered beech-wood yielded the formula $C_{33}H_{25}O_{24}$. It is, then, evident, that the mode of decomposition varies according to the more or less free access of air; that where it is freely admitted, decay takes place; where restrained, both decay and putrefaction. It is probable that the oxygen of the water assists in the formation of carbonic acid. A specimen of brown coal, still retaining the organic structure of wood, gave $C_{33}H_{21}O_{16}$, which is the same as wood, less 3 eq. carbonic acid, and 1 eq. hydrogen; and all varieties of such coal contain more hydrogen than wood, and less oxygen than is sufficient to produce water with all the hydrogen. It hence appears to have been formed by a process analogous to the putrefaction of wood above noticed. In the decay of wood in marshes where the access of air is almost excluded, carburetted hydrogen is also evolved with carbonic acid, and in the gradual change of coal the same gases are generated.

Fresh impure gluten evolved by its putrefaction, in 5 weeks, 28 times its volume of gas, consisting of 21 vols. carbonic acid and 27 vols. hydrogen, while phosphate, acetate, caseate, and lactate of ammonia were produced at the same time, and when the supply of water is renewed, besides the above, there are formed carbonate of ammonia, sulphydrate of ammonium, caseous oxide, and a mucilage coagulable by chlorine. In the putrefaction of cabbage for preparing a sour food, acetic and lactic acids are formed in such quantity as to give an acid taste to it; and when the putrefaction is pushed a little farther, the odor of ammonia and sulphuretted hydrogen are developed.

The tendency to decay is stronger than to putrefaction, from the stronger affinities which oxygen brings into action; and this tendency exists whether air be excluded or not. Bodies subjected to putrefaction with limited access of air, tend to abstract oxygen from surrounding bodies; so that it is probable that even water is decomposed. Hence putrefaction is a powerfully deoxidizing process. Blue indigo may be deoxidized and rendered colorless by contact with putrefying organic matter, in presence of a base. A solution of gypsum (sulphate of lime) mixed with putrescible organic matter and kept in a close vessel, will be decomposed into carbonate and sulphuret.

Crystallized pyrites is observed to form on decaying roots in stagnant water, containing sulphates in solution. On the tropical western coast of Africa, sulphuretted hydrogen is largely developed from decaying water-plants near the shore. The pyrites found in coals is due to the same cause. *Liebig*.

During putrefaction microscopic animal life is largely developed; animalcules suddenly spring into existence at its commencement, and are succeeded by other successive races in their turn. A vast number of infusory animals have been found in stagnant water, but no attempt has yet been made to connect peculiar genera or species with peculiar states or stages of chemical decomposition. That they are the cause of the decomposition, cannot be plausibly affirmed. Cheese and flesh may putrefy without the slightest development of animal life. They exist, feed, grow to a certain size, give off excrements which decompose like other excrements, and dying, their bodies likewise enter into putrefaction. That the mode of existence in some of these animalcules is anomalous, is proved by observations made on them long since by Count Rumford, and latterly by Pfankuch, August and Morren, and Liebig, who have all observed the development of oxygen gas from the water containing them, although a powerful microscope could not detect any vegetable matter suspended in the liquid. A wide field is here opened for investigation, for, as Liebig observes, "We recognise in these animals, or perhaps only in certain classes of them, by means of the oxygen which in some way, as yet incomprehensible, accompanies their appearance,—a most wise and wonderful provision for removing from water the substances hurtful to the higher classes of animals, and for substituting in their stead the food of plants, carbonic acid, and the oxygen gas essential to the respiration of animals." But although animalcules may often accompany putrefaction and hasten its completion, they are not essential to the process, which may take place independently of them, and may doubtless be investigated as a series of chemical changes. Since we admit several varieties of fermentation, giving distinct results, but bound together by the same general law of decomposition, we must infer that there is a large series of putrefactive changes, agreeing in one general principle of transformation, and in their ultimate products but widely differing in the substances themselves and in those formed successively between the first and last products, between the complex putrescible bodies and their final, simpler, inorganic constitution.

Preventives of Putrefaction. Since the delicate tissues, food and other complex organic substances employed for the necessities and conveniences of life are very liable to putrefaction, the desire to protect them from this change has given rise to numberless experiments, with varying success. Air, water and certain limits of temperature promoting putrefaction, the exclusion of air, desiccation, and a different temperature prevent it. Below 32° or at 212° , bodies will not putrefy; and when already in progress, the heat of 212° will

effectually arrest and prevent the change. But although when cooled below 32° putrefaction is arrested, when the temperature again rises, many bodies seem to undergo putrefaction more readily than before. Not so with those heated to ebullition, which seem less putrescible than before, and may be ascribed to a solidification or coagulation of albuminous matter. Above all things, the contact of putrid matter with fresh putrescible matter should be avoided.

Vegetable and animal matters are preserved by salts and other substances having an attraction for water, by sugar, vinegar and other acids, and by substances which coagulate or render insoluble albuminous matter, as alcohol, creasote, tannic acid, corrosive sublimate, salts of copper, iron and other metals. In choosing the preservative, regard is had to the special object in view; for the preservation of food, poisonous mineral substances cannot be used; for preserving timber, pyrolignite of iron is effectual and economical; tannic acid preserves hides, by uniting with gelatin to form insoluble leather.

FERGUSONITE. *Min. Descrip.* Cryst. Quadratic. $H. = 5.5 - 6$. $G. = 5.8 - 5.838$. Color, brown; lustre externally dull, brilliantly vitreous on fracture; sub-translucent, opaque; fracture perfect conchoidal, with pale brown streak. *Chem. Rel.* Infusible; gives with difficulty yellowish beads while hot with borax and mic. salt, the latter reddish when reduced or saturated; soda decomposes without dissolving it, and on charcoal yields spangles of tin. Probable formula $\begin{matrix} 6 \text{ YO} \\ 6 \text{ CeO} \end{matrix} \left\{ \text{Ta}_2\text{O}_3 \right\}$, consisting of columbic acid with yttria, zirconia and the oxides of cerium, iron, uranium and tin. Compare **Yttrio-columbite**. Found at Cape Farewell, Greenland.

FERN. The name of a large class of plants, but especially applied to the buds and root of the *Nephrodium* or *Aspidium Filix-mas*. The dry root, which is of a feeble, disagreeable odor, and nauseous, rancid taste, contains, according to Geiger's analysis,

Green fat oil	6.9
— resin	4.1
Uncrystallizable sugar	} 22.9
Easily oxidizable tannin	
Gum and salts, with sugar and tannin ..	9.8
Ligneous fibre and starch	56.3

100.0

Wackenroder found volatile oil in addition to these components.

The anthelmintic property of the root doubtless resides in the fat oil (*Oleum Filicis*), which forms 10 to 11 pr. ct. of its composition, and can be extracted by ether.

Oleum Filicis. The æthereal extract of the above root. It contains, besides fat oil, coloring matter, extractive, salts and resin. Dr. Luck (*Ann. der Chem. und Pharm.*, 1845) has lately made an examination of this substance. By his analyses it appears that several of its components are indurated with acid properties.

Ferns generally yield ashes containing a large proportion of potassa, and on this ac-

count are employed in porcelain manufacture in China.

FERROCYANIDE, FERROPRUSSIATE, FERRIDCYANIDE, FERRURETTED CHY-AZIC ACID. See **CYANOGEN**.

FERRUGINOUS, Containing iron. *Lat.* Ferrum.

FIBRIN. *Chem. Phys.* Exists in the animal structure as the basis of the muscular tissue, and in the vegetable kingdom as a constituent of the juices of plants. It occurs also in solution in lymph, chyle, and blood, from which it separates by coagulation, as soon as these fluids cease to form a part of the living organism. It has also been found, by Zimmermann, in the urine of pleuritic patients, in certain stages of the disease.

Prep. By carefully whipping blood, it separates in elastic, stringy masses, which must be washed repeatedly with water to remove coloring matter, and digested frequently with alcohol and ether, to free it of fatty substances. The presence of sulphate of soda or nitrate of potassa prevents the coagulation.

Prop. When dry, is an opaque, yellowish mass, the slightest transparency of which indicates the presence of traces of fat; insoluble in alcohol and ether. By long digestion in water at 390°, is dissolved with slight decomposition, but is thrown down again by the acids; the precipitate by acetic acid being soluble in an excess of that re-agent. Its solubility in saline solutions has been tested: when saturated, it forms clear, viscid liquids, generally coagulable by boiling. The water and flexibility which it loses by evaporation in vacuo, is regained by a lengthened soaking in that liquid. When burned it gives off the same smell as albumen, and yields ashes composed of the phosphates of lime and magnesia. Unlike albumen, it is said to have the property of decomposing binoxide of hydrogen catalytically with the evolution of oxygen and heat; but according to Scheerer, this power belongs only to the fresh and unboiled fibrin.

In sulphuric and mono or bibasic phosphoric acids it becomes gelatinous, and forms a neutral compound, soluble in water. Nitric acid converts it, with the evolution of nitrogen and nitric oxide, into a yellow powder, *xantho-proteic* acid. When dry it forms a blue solution in strong hydrochloric acid. From its acid solutions it is precipitated by ferrocyanide and ferridecyanide of potassium. Its solution in caustic potassa is coagulated by alcohol and acids, but not by heat. Muscular and venous fibrin both dissolve, at a gentle heat, in acetate of soda, muriate of ammonia and nitrate of potassa, forming solutions coagulable by heat, and exhibiting the properties of dissolved albumen; but neither arterial fibrin nor that of the buffy coat can undergo this change, and even the venous loses the property after exposure to air, by the absorption of oxygen and the emission of carbonic acid. By putrefaction it is transformed into a volatile fatty body, having the characteristics of butyric acid. The same result is produced by heating it with potash lime at 320° to 356°. (*Wurtz.*) See the observations of Blondeau under **FATS**.

Formula, $C_{400}H_{310}N_{50}O_{120}SP$ or $10Pr + SP$. Hence its identity in composition with **ALBUMEN**, from which it differs only in the absence of the soda compound, to which is due the property of the latter of forming an apparent solution in water. Vogel, however, found more nitrogen in fibrin than in albumen, and Cahours and Dumas' experiments show the presence of less carbon. The opinions of the latter chemists, that fibrin is albumen combined with a minute portion of ammonia, has been shown, by Berzelius, to be incorrect. *An. Rep.* 23, 586.

Pure fibrin, when added to water acidulated with HCl acid, and containing yeast, forms a clear solution similar to that of protein, and from which acid and alum precipitate a flocculent body. Without yeast, a temperature of 212° will cause the same result. By evaporation in vacuo it leaves a light yellow residue analogous to dried egg-white, soluble in warm water, but not coagulable by heat. After separating the dissolved from the acid, it has a composition closely approximating to *Chondrin*, but without its chemical properties. (*Dumas*.) Schlossberger's recent analysis of pure fibrin gave 15.51 as its per centage of nitrogen, being only .21 less than that found by Mulder, and upon which the above formula is based.

FIBROFERRITE. *Min.* A yellow copperas from Chili, examined by Prideaux, having the formula $2Fe_2O_3, 3SO_3 + 18HO$ or $3Fe_2O_3, 5SO_3 + 27HO$. It is partially soluble in water, wholly soluble in muriatic acid, leaving a little sulphur and earthy matters.

FIBROLITE. *Min.* According to A. Erdmann's analysis, a specimen from Chester Co., Pa., of spec. grav. 3.239, yielded

Silica.....	40.05
Alumina.....	58.88
Oxide of iron.....	0.74
	99.67

according to which, its formula is $4Al_2O_3, 3SiO_3$, or the same as Andalusite, with which it closely agrees in hardness, spec. grav. and crystalline form. (See **BUCHOLZITE**.)

FICHELITE. *Min.* From the brown coal of Uznach, in the Fichtel mountains. Occurs in prismatic needles of a pearly lustre, lighter than water, fuses at 115° and distils over as a liquid, in both cases congealing to a crystalline mass; is slightly soluble in alcohol, readily in ether. Formula C_4H_3 . Berzelius thinks it may be a mixture of Phylloretin and Tekoretin.

FIGURE-STONE. See **AGALMATOLITE**.

FILTRATION. *Tech. Chem.* The straining or mechanical separation of a liquid from pulverulent solid matter, and of a few liquids from each other.

The importance of the process in **ANALYSIS**, is mentioned at p. 170. In the arts it is no less useful and convenient. There is no chemical change produced upon the substances subjected to the operation; the process is purely mechanical, being dependent upon capillary action. The liquid passes

through the fine pores which intercept the solid particles, and therefore the filter, when of paper or other material, requires porosity.

Separation of liquids by filtration depends entirely on the filtering media being more impervious to one of the ingredients of the filtering mixture than to the other, as oil and water. Filters are of various kinds; for small operations, cones of bibulous paper (Figs. 12 to 16, under **ANALYSIS**), supported by a common funnel, answer every purpose. In extensive laboratories, square covered frames, or conical bags are substituted. The material of which these are formed depends entirely upon the nature of the substances to be filtered: muslin, duck, crash, linen, flannel, felt-cloths, raw cotton, straw, coarse sand or silex, animal and vegetable charcoal, each has its appropriate application. Infiltration through beds of porous ingredients is effected by the **DISPLACEMENT** apparatus.

Filters for clarifying water may be constructed of charcoal or sand, or both, in separate layers, the best form being those which are capable of being reversed. A compact filter of this form, used in Philadelphia, is that of Jennison, either end of which, screwed to a hydrant, allows clear water to pass through rapidly, by its pressure; when it becomes clogged with sediment and the other end is attached to the hydrant, the water pressing through carries off the deposit, and then passes a clear liquid.

FIORITE. See **OPAL**.

FIRE. See **HEAT. COMBUSTION**.

FIRE-DAMP. See **HYDROGEN**.

FIRE-WORKS. See **PYROTECHNY**.

FISCHERITE. *Min.* A green mineral, allied to Turquoise or Calaité, from Nischnei-Tagilsk, crystalline, translucent; spec. grav. 2.46. According to Herrmann's analysis, after abstracting a little phosphate of copper and iron, it appears to be $2Al_2O_3, PO_5 + 8HO$. *Ram*.

FISH-SCALES. The thin, transparent plates forming the exterior defensive coating of many genera of fish, and by their structure also regulating the classification of them. *Agassiz*.

The scales of the amphibia are analogous in composition to horn and hair, as are probably those of all other fish.

FIXED AIR. See **CARBON**.

FIXED BODIES. Those which resist the high furnace temperatures. So termed, in contradistinction to volatile bodies, though this latter property varies in different bodies, through a wide range of temperatures.

FIXED OILS. See **OILS**.

FLAME. Flame is the rapid combustion of volatile matter. The combustible unites with oxygen, evolving light and heat, while new compounds are generated. (See **COMBUSTION**.) Iron unites with oxygen, burning brilliantly without flame, because it is not volatile, while fine zinc turnings held to a lighted candle burn with a brilliant flame, because zinc is volatile. Sulphur being volatile burns with flame, while carbon, which is fixed, burns without. Any combustible gas, therefore, will burn with flame, such as hydrogen and many of its compounds, with carbon, sulphur, &c.,

as also carbonic oxide and other gases. The resulting bodies are those of combustion, sulphurous and carbonic acids being produced from sulphur and carbon, oxides of zinc and iron from the metals zinc and iron, water from hydrogen. In all ordinary cases of combustion the resulting products are carbonic acid and water, because the combustibles employed are composed of carbon and hydrogen, with or without oxygen.

The *color and brilliancy* of flame are due to solid particles carried up with it in a state of intense ignition. If a cold body, as a white saucer, be held in the flame of a candle, lamp or gas jet, carbon will be deposited on it in the form of lamp-black, which carbon is indeed the cause of the luminosity of flame in all ordinary cases. Hydrogen burns with a feeble, yellowish flame; carburetted hydrogen with a more luminous flame. Hydrogen and oxygen mingled, burn with a feeble light; but if the jet be directed upon a piece of lime or clay, a dazzling light is produced, which is due to particles of lime or alumina mechanically thrown off in an intensely ignited state. In like manner the whiteness and brilliancy observed in the flame of burning phosphorus, is due to highly ignited phosphoric acid, which is the result of combustion. Oxide of zinc, resulting from the combustion of the metal, produces a brilliant, bluish-white flame. Salts of strontia and lithia impart a brilliant red color to flame, and hence the use of the former for obtaining a brilliant crimson in fire-works. Borax and barytic salts give a green tint; copper salts both green and blue colors to flame.

Measure of Luminosity. The illuminating power of flame is measured by a photometer, which, as usually constructed, consists of an oblong box open on two opposite ends, with two mirrors placed at such an angle that the reflection of two flames, one placed opposite either open end of the box, is thrown upward upon a small screen of white paper or other translucent material in the centre of the top of the box. The two reflections appearing side by side upon the screen, enables the observer to judge of their comparative intensity, and by moving one of the flames further from or nearer to the box, he can determine, with some degree of nicety, when the two reflections are of equal intensity. By observing the relative distance of the two flames from the centre of the box, and knowing that the intensity is inversely as the square of the distance, an approximate value of relative intensity may be attained by calculation. In any one series of experiments, the determinations may be of value, because the same standard, such as a certain gas-jet, may be employed; but, for want of a fixed standard, similar experiments, instituted by different individuals and in different places, are of very limited value. The tallow mould-candle, used as a standard, must be rejected as worthless, since the material is not uniform in composition, and the light varies also with the thickness of the candle, the thickness, twist and length of wick. A far more suitable material is pure spermaceti, which is crystalline, uniform in

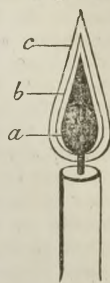
composition, and from the thinness of the wick is less liable to variation from this cause.

Structure. Fig. 73 represents the structure of the flame of a candle, and applies to all flames used for illumination. *a* is the interior cone of volatilized combustible matter, not ignited; the next outer cone, *b*, consists of this combustible gas in the act of union with the oxygen of the air, and is the cone of illumination; the outermost cone, *c*, emits a feeble light, and consists of the gaseous products of combustion in a highly heated state, as they leave the cone of combination; or, rather, it consists of these, together with a small quantity of unburned matter undergoing complete combustion. That the interior cone consists of volatilized matter not ignited, might be inferred from its comparative darkness, and may be proved by thrusting one end of an open tube into this cone, holding it in an oblique position, and burning the gas which issues at the other end of the tube. In the middle cone, the hydrogen of the body being most combustible is first burned, and the carbon eliminated or precipitated; but the intensity of the heat resulting from the union of hydrogen and oxygen, ignites this solid carbon intensely previous to, and during its combustion. The faintness of the exterior cone is due to the admixture of the incombustible products of combustion, steam and carbonic acid, with small quantities of yet unburned carbon, as may be shown in the long cone of light over a lamp in a coal-mine, where the air contains carburetted hydrogen gas. This appears to be a slower combustion, in consequence of the great diffusion of the combustible matter.

The *heat* of flame is more intense than might at first be supposed. If a fine platinum wire be held across the flame of a spirit-lamp just above the wick, both its structure and intense heat will be shown; for while the centre of the wire is dark, on either side of this it is heated to a white heat. If the same wire be held some distance above the flame of a Berzelius' spirit-lamp, it will still be heated to 'full redness, showing the intense heat of the gaseous matter, after issuing from flame. The table and mouth-blowpipes illustrate the same point. A high degree of heat is requisite to produce inflammation. Charcoal may be ignited by a spark; tallow, oil or gas requires a flame to inflame it. When phosphorus is inflamed by a spark, the latter first produces a high chemical action, and therefore intense heat, which causes the phosphorus to inflame.

Cooling flame. Both the light and heat of flame are capable of increase or diminution within certain limits. A flame may be cooled down so far, that the gaseous matter ceases to burn. When a piece of metal or other cold body is held across a flame, a large amount of carbon is deposited, which would otherwise have burned and added to the flame. When

Fig. 73.



a sheet of close wire-gauze is similarly held across the middle of a flame, the latter is cut off, and its combustible matter passes through the gauze uninflamed, as shown by its inflammation upon applying flame above the gauze. This fact was discovered and ingeniously applied by Sir H. Davy, to his safety lamp, which consists of a wire-gauze cylinder surrounding an oil lamp, the inlet and outlet to the flame being also through fine metallic openings. When this lamp is plunged into an explosive mixture of carburetted hydrogen and air, explosion does not immediately ensue; but a quiet, slower combustion takes place on the outer surface of the gauze, which may then become so highly heated as to explode the mixed gases. Its object was to secure the collier from the disasters incident to such natural explosive mixtures in coal-mines; but although much improved in its construction, it has not fully answered the purpose.

Smoky flames. If a white flame be cooled down in the manner described, unburned carbon is deposited, and the flame observed to smoke. Indeed, when the intensity of chemical action in such a flame is insufficient, a large portion of carbon is carried up mechanically, and makes a sooty or smoky flame. Those bodies having a small quantity of hydrogen and oxygen relative to carbon, are most apt to produce smoky flames. Thus, spirit of wine burns with a pale flame, without smoke, spirit of turpentine with a very smoky flame; for while the former abounds in hydrogen and oxygen, the latter has a smaller amount of hydrogen and no oxygen. Since the smokiness of flame is caused by deficiency in chemical action, it is obvious that it may be prevented by blowing a stream of oxygen or air through the flame. If a strong blast from a blowpipe be directed through a smoky flame, it supplies so much oxygen in a given time, that the excess of depositing carbon may be intensely ignited and produce a clear, white flame; if the blast be increased, the carbon and hydrogen are simultaneously burned, and the flame is a faint reddish or yellowish. A similar effect is produced by increasing the supply of air to a smoky flame, by a chimney which, when of suitable dimensions, will reduce the flame to a clear, brilliant light. If the chimney be too small, there is a tendency to smoke; where too large, it reduces the flame below its maximum brilliancy.

Sources of Flame. For purposes of illumination, gas, oil and candles are employed. The first being already in the gaseous state, no farther preparation is requisite than to apply a flame to it, when it instantly inflames. Oil is burned at the end of a wick composed of loosely-twisted fibre, to which point it is carried by capillary action. Flame being applied at that point, the oil must first boil or be converted into vapor, which then inflames like gas. The distance of the flame above the surface of oil in the reservoir, is limited by capillary attraction. The inflammation of a candle differs from that of oil, in requiring a little heat first to melt, and then boil the combustible, so that the latter must always be sufficiently near the short wick to be melted

by heat from the flame. When the wick of a burning candle is suffered to become too long, a large amount of melted matter is carried up and boils, and more gas is generated than is proportional to the supply of air, so that it smokes, gives less light, and at the same time consumes more combustible. The same remark applies to small, single-wicked lamps for oil. (See CANDLES, LAMP.) The purity or composition of the combustible has considerable influence on the clearness of flame; for if oil or tallow contain mucilage, &c., this will form a hard crust on the wick, enlarge it, and tend to produce smokiness.

Use in the Arts. Besides the employment of flame for illumination, already treated of more fully, it is very useful and almost essential in some of the arts, as in pottery, glass making, or puddling iron, in which the fuel should not be mingled with the material to be heated. The reverberatory furnace is expressly constructed with the view of separating the material from the fuel, and hence wood or bituminous coal is generally employed in them. If bituminous coal be employed, a strong draft is requisite, in order to consume as much as possible the excess of carbon in its usually smoky flame; and a little air admitted, just over the fire, has been found advantageous. Rosin has latterly been employed, in the U. S., for melting glass, and produces a beautifully clear flame, by constantly adding very small quantities at a time, to the fire. Anthracite has been used for fuel in puddling or heating iron, by regulating the admission of air below the fire, so as to produce carbonic oxide, and then blowing currents of air through this heated gas, above the fire, whereby a flame of great heat is obtained.

FLESH. Phys. A compound of the softer solids of the animal body. Their proportions are shown by the following analyses.

The flesh of man contains, according to

	Marchand & L'Heretier,	
Water and loss	78.00	77.10
Matter insol. in cold water	17.00	15.80
Sol. albumen, with coloring matter.....	2.30	3.40
Alcohol. extract with salts .	1.60	1.20
Phos. lime, with albumen .	0.10	—
Water extract, with salts..	1.00	2.50

The flesh in the first analyses was taken from the upper portion of the arm of a man who died from diseased liver.

The constituents of the flesh of oxen are

	Berzelius.
Water	77.17
Fibrin, cells, vessels and nerves...	17.70
Albumen and hæmatoglobulin....	2.20
Alcoholic extract and salts	1.80
Water extract and salts	1.05
Phosphate of lime, with albumen..	0.08
Fat and loss	—

Schlossberger's analyses of the flesh of other animals, to which that of Schultz corresponds in many points, are given in Simon's *Chemistry of Man*.

FLINT.

The analyses of Playfair and Bœckman establish $C_{48}H_{39}N_5O_5$ as the formula for the ultimate composition of flesh. The numerical results upon which this formula is based being identical with those from dried blood, it is also considered the empirical formula for that substance.

Liebig, in some recent investigations, has shown the presence of free lactic and phosphoric acids in the muscular part of flesh. Besides these and the CREATIN of Chevreul, there are two other new crystalline azotized bodies, (*Comptes Rendus*, 1847.) Another ingredient also, of fresh meat, is a positive organic base, analogous in constitution to *Chinin*, or more nearly to *Codein*.

The action of cold water upon finely minced meat transforms it into a white residue, which is actual muscular fibre. By boiling, the soluble ingredients of the meat are taken up in the water, and hence, as the alkaline phosphates are necessary to the formation of blood and consequently of flesh, the loss of them by the exhausted meat renders it unfit for nutrition, unless eaten with the soup or extract. This latter, again, wanting in the materials of albumen and fibrin, is also not thoroughly nourishing in itself alone; but as it contains all the ingredients of the acid gastric juice, it is considered an efficient digestive adjuvant in cases of dyspepsia. It is in its roasted state, however, that flesh embodies the most nutritive power.

The brine of salted meat abstracts and retains all the phosphates, acids, creatin, &c., necessary to the formation of blood: and hence its scorbutic action, owing to a partial reduction, by this process, to a mere supporter of respiration, and hence its inability to effect the perfect replacement of the wasted organism.

Meat, when first placed in cold water and then boiled, becomes harder and more tasteless than if boiled in water previously heated, because the matters grateful to the taste and smell are imbibed by the broth. In the latter case, however, the coagulation of the albumen presents a layer impermeable to water, and thus, while impairing the quality of the soup, renders the meat highly palatable. *Liebig*.

FLINT. *Min. Geol. Tech.* A nearly pure, amorphous or chalcedonic QUARTZ, found in chalk in nodular masses, isolated or in layers, constituting beds of such extent as to be sometimes employed for building, and extensively in the manufacture of pottery and porcelain. It is nearly pure silicic acid; in addition to which Berzelius found in flint, from the chalk of Limhamm in Schonen, 0.117 pr. ct. potassa, 0.113 lime, traces of iron and alumina, and a carbonaceous residue, which burned without remainder. The interior of a specimen externally disintegrated, yielded 0.134 pr. ct. potassa, 0.574 lime and 0.12 iron and alumina, while the white exterior coating gave 0.32 pr. ct. potassa and as much lime, from which it would seem as if the change took place in an alkaline liquid, where the lime is replaced by potassa. The carbonaceous matter is the cause of the dark color of flint, but not always: for Heintz found that flint from the

FLUORINE.

Jura formation is not decolorized by ignition in oxygen.

Their connection with organic life may be inferred from the carbonaceous matter, the shells around and sometimes within them, and from a little sulphur rarely found in the cavities of a flint-geode; the sulphur being probably due to the reduction of sulphuric acid, by putrefaction of organic matter.

Flint nodules are broken into gun-flints by hand and hammer alone; and if we consider their cheapness and uniform shape, the dexterity of the operatives is a matter of surprise. A good workman can finish 3 to 400 per day. Independently of skill, their manufacture depends on the smooth and large conchoidal fracture of flint.

For fine pottery and porcelain, flint is calcined and ground to a fine powder. The same material was formerly much used as the basis of glass, to one kind of which it has imparted the name flint-glass; but white sea-sand is now generally substituted.

FLOATSTONE. A variety of QUARTZ.

FLOS FERRI. *Min.* The flower-like, coral-loidal form of ARRAGONITE.

FLOUR. This term is occasionally given to the meal of the cereal grains, and in some instances to that of other seeds; but is almost exclusively applied to the finely ground and bolted farina of WHEAT. See BREAD.

FLOWERS. A term originating with the older chemists, and by them applied to the light, flocculent compounds of bodies, produced by sublimation in close vessels; for example, the flowers of sulphur, antimony and benzoïn.

FLUCERIN. *Min.* There are two species, neutral and basic, which may be termed Flucerin and Fluoxycerin. *Flucerin*, or neutral fluoride of cerium. Cryst. Hexagonal, prismatic and lamellar, also amorphous. $H. = 4 - 5$. $G. = 4.7$. Dark tile-red, or nearly yellow, with a white, or slightly yellowish streak: lustre feeble; subtranslucent, opaque. In a closed tube gives a little water, and at the fusing heat of glass fluohydric acid, becoming white; infusible on charcoal; behaves to the fluxes like pure oxide of cerium; decomposed by soda. Form. $CeF + Ce_2F_3$, with 1 pr. ct. yttria. It occurs at Finbo and Broddbo, near Fahlun, Sweden, in quartz and albite.

FLUELLITE. *Min.* Cryst. Right-rhombic, generally the 8-hedron. $H. = 3$. White, transparent. Contains fluohydric acid and alumina. Found at Stenna-gwyn, in Cornwall.

FLUID. *Phys.* Bodies are solid, liquid or gaseous, the two last of which are termed fluids: the ready movement of their particles allowing them to flow.

FLUIDITY. *Phys.* Is exclusively applied to liquids, for distinguishing the greater or less freedom of motion among their particles.

FLUORINE. *Chem. Ger.* Fluor. One of the halogen bodies, known only in combination. It is rather a rare substance, being most abundant in fluor-spar. It is also found in some Micas, Topaz, Chondrodite, and a few other minerals, several of which contain cerium. It is further a constituent of bones, teeth, milk, blood, urine, plants, sea-water, and of well and mineral waters. It has also been

found in nearly all calcareous and mineral deposits of aqueous origin, in the organic remains of carnivora, herbivora, reptilia and pisces.

Etching by means of fluor spar was observed by Schwankhard in Nuremberg, in 1670; Scheele separated fluoric acid from the spar in 1771; and Ampère, in 1810, supposed it to be composed of a base fluorine, and hydrogen, analogous, therefore, to muriatic acid. Berzelius, in 1824, published his extended researches on fluorine, since which it has received but little attention. $\text{Eq.} = 18.7$ (or 233.8 when $\text{O} = 100$). Sym. F or Fl.

1. *Fluorine*. The radical of fluoric compounds has been isolated; but such are its intense affinities, that we know no more of it than that it is a gas, probably of a yellowish color and a halogen odor. The Knoxes employed transparent vessels of fluor spar to receive the gas.

2. *Fluohydric Acid*. Syn. Fluoric acid. *Ger.* Flusssäure, Fluorwasserstoffsäure. Prepared by gently heating in a retort of platinum or lead, 1 pt. pulverized fluor spar with 2 pts. oil of vitriol, and receiving in a platinum or lead vessel, cooled by ice; $\text{CaF} + \text{SO}_3, \text{HO} = \text{CaO}, \text{SO}_3 + \text{HF}$. If silice be in the spar, as is generally the case, fluoride of silicon also passes over; if galena, then sulphuretted hydrogen and sulphurous acid are also generated, and sulphur is deposited in the fluoric acid. It is a colorless liquid, of a very pungent odor, injurious to the lungs, smarting and producing a wound when dropped on the skin; reddens litmus; spec. grav. = 1.0609; does not freeze at $+4^\circ$, boils at a little above 59° . When decomposed by a galvanic battery, hydrogen appears at the $-$ pole, while the $+$ electrode, if platinum is converted into a brown fluoride; it is also decomposed by potassium (violently); by sodium, iron, zinc, manganese, silicium and columbium, into hydrogen and a metallic fluoride; by most metallic oxides into water and a fluoride; by silica into fluosilicic gas and the liquid fluosilicic acid. It dissolves readily in water with heat, and with a certain proportion attains the spec. grav. of 1.25. The liquid acid may be readily made, by conducting the lead or platinum beak of the retort over water, and may be freed from silica by dropping fluoride of potassium into it as long as a precipitate occurs, which is silico-fluoride of potassium, and redistilling. It is preserved in vessels of platinum, gold or lead; but the latter, as well as the lead retort, should not be soldered with tin. When employed in the analysis of silicates, a broad leaden vessel is used; see fig. 25, p. 185, ANALYSIS; and a similar broad vessel of lead is convenient for etching on glass.

Fluorides. Fluorine has not yet been combined with oxygen, carbon or nitrogen, but it unites with all other elements. Metallic fluorides are formed by the action of fluoric acid on some metals evolving hydrogen, on most metallic oxides forming also water, or, if the fluoride be volatile by distilling fluor spar, the metallic oxide and oil of vitriol. Fluorides bear some resemblance to chlorides, most being fusible and some volatile, as those of tita-

nium, chrome, arsenic, and nearly all decomposable by heating with oil of vitriol. Some of the simple fluorides are readily soluble in water, as those of glucinum, aluminum, silver, tin; others less soluble, as potassium, sodium, iron, platinum; some very little, lithium, strontium, lead, cadmium, copper, bismuth; while many are not at all soluble, baryum, calcium, yttrium, manganese. The neutral solutions of alkaline fluorides have an alkaline reaction. Many of the simple fluorides combine with fluohydric acid, sometimes to crystallizable compounds; even the insoluble salts of baryum and calcium are soluble in fluohydric acid. The terfluorides of boron and silicon, acting like acids, form numerous salts with the simple fluorides. The fluorides of phosphorus and sulphur act similarly, but with less energy. The fluorides of aluminum, iron, chrome, uranium, platinum, titanium, tungsten, columbium, vanadium and a few others, also combine with more electro-positive fluorides, to form salts. For the compounds of fluorine, refer to the several bases.

Analysis. The simplest test for the presence of fluorine, is to decompose its compounds by oil of vitriol with gentle heat, in a vessel of lead, covered by a glass plate which has been covered by a thin layer of wax, and graved through to the glass in a few lines. After melting and rubbing off the wax the lines will be found etched in the glass, if fluorine were present. The best method of determining fluorine quantitatively, is to mix the weighed substance with silica, and introduce it into the flask *a*, fig. 26, p. 188, under ANALYSIS, and after partly filling the bulb *c* with concentrated and boiled oil of vitriol, and weighing the whole apparatus, to let the latter down upon the mixture. When a portion of fluosilicic gas has escaped, the flask is heated to expel more, and the last portions removed under the air-pump. When weighed again, the loss in weight is fluoride of silicon, of which 1.395 pts. are equivalent to 1 pt. of fluorine, (or 10 pts. loss of weight = 7.168 fluorine). Moisture and carbonic acid should have been previously ascertained; and the latter may be removed by dilute acid. (*Wohler*.) Barytic salt should be employed for precipitating fluorine, as fluoride of calcium is slightly soluble in water.

FLUOR SPAR. *Min.* Syn. Octahedral Fluor-Haloid, *M.*, Fluat of lime, Chlorophane, Ratoffkil, Derbyshire spar. *Ger.* Flussspath. *Fr.* Chaux fluatée. Muria phosphorans. (*Linn.*) *Descrip.* Cryst. Regular, usually the cube, its edges bevelled by the 4×6 -hedron, or its solid angles replaced by 3 planes of the 24-hedron, or by 6 planes of the 6×8 -hedron; it also exhibits the 8-hedron and 12-hedron rarely alone. Cleavage perfect parallel to 8-hedron. It is sometimes compounded on a plane of the 8-hedron, as in Pl. IX. fig. 52, or as one cube within another on a diagonal. It also occurs granular, coarse and fine, nearly compact. $\text{H.} = 4$, $\text{G.} = 3.14 - 3.178$. Colors violet, sky-blue, green, white, rose and crimson-red, yellow, brown and intermediate shades; violet is the most common color. The colors are often concentric, and the cube may have a

FLUOXYCERIN.

violet centre and greenish exterior. Lustre vitreous, sometimes splendid, glimmering in the compacter and massive varieties; transparent, subtranslucent; brittle, with a splintery fracture; flat—conchoidal in the massive.

Chem. Rel. At a low heat fluor spar phosphoresces with various colors, the variety chlorophane with an emerald green light; this property ceases at a high temperature, but is restored by an electric discharge. Decrepitates strongly when heated, and fuses in thin laminæ to an enamel; according to Kœbell, at a high heat it becomes infusible, alkaline, and colors the flame red. Borax, mic. salt and a little soda dissolve it; fuses with gypsum or heavy spar to a clear bead, which enamels on cooling. Partially decomposed by muriatic and nitric acids, fully by oil of vitriol. See Fluohydric Acid, under FLUORINE. See Fluoride, under CALCIUM, for its per centage, composition, its uses and behavior. Formula CaF_2 ; but it often contains impurities, siliceous, iron, &c. Berzelius found $\frac{1}{2}$ pr. ct. phosphate of lime in Derbyshire spar; and Kersten says that several blue varieties from Marienberg and Freiberg gave small quantities of chlorohydric acid.

Local. It is abundant in primary and secondary rocks, especially in the mining districts of England and Saxony. In the U. S., on the borders of Muscalonge lake, Jefferson Co., N. Y., large cubes, more than 1 ft. diameter, have been found; Rossie and Johnsberg, St. Lawrence Co., Lockport, Rochester, Manlius, Amity, N. Y.; Gallatin Co., Illinois, for 30 miles along the Ohio, deep violet masses near Shawneetown; Westmoreland, N. H., white, green and violet; the Notch, in the White Mts., green 8-hedra; Smith Co., Tennessee, white and violet; Trumbull, Conn., Chlorophane. There are numerous other localities.

FLUOXYCERIN, or Fluoride and oxide of Cerium. Usually massive, with traces of the rhombic 12-hedron. $H. = 5$. Color and streak fine yellow, or brownish-yellow when impure; lustre vitreous; subtranslucent, opaque. Differs from flucerin in becoming black on charcoal, and red or dark yellow when cold, and is not as easily decomposed by soda. Form. $\text{Ce}_2\text{F}_3, 3\text{HO} + \text{Ce}_2\text{O}_3, \text{HO}$. It occurs at Bastnäs and Finbo, Sweden. The presence and amount of lanthanum and didymium have not been determined.

FLUX. *Tech. Chem. Ger. Fluss.* A substance employed to vitreify or fuse earthy bodies, the *flowing* of the melted mass giving rise to the term flux. Thus the earthy ingredients of metallic ores are fluxed, or caused to flow off from the metallic particles, allowing them thereby to collect into masses; sand is fluxed to form glass; sand and clay together are semifluxed, to form them into more adherent and compact pottery and porcelain. Siliceous (silica, silicic acid) being the most abundant foreign ingredient in ores, &c., is the body generally fluxed; and from its acid nature as well as its forming fusible salts and mixtures with alkaline bodies or strong bases, these last are the most common fluxes.

Objects of Fluxing. In the manufacture of glass and pottery, the main object is the fluxed

FLUX.

material. In the former the basis is pure siliceous, which forms very fusible mixtures with the alkalies, potassa and soda, to which, for window and plate-glass, lime is adjoined; for flint-glass, oxide of lead (red-lead, litharge); for coarse bottle-glass, oxide of iron and alumina. In pottery, the basis being a mixture of sand and clay, which are not only infusible, but barely adhere together by a strong heat, lime and feldspar (containing potassa) are added in limited quantity to induce a strong adherence, as in pottery, or a semi-fusion, as in porcelain. These mixtures are capable of fusion, but not at the temperatures employed in their baking. A more fusible mixture is brought upon their surface, which is actually fused, and constitutes the glazing. See GLASS and POTTERY.

The objects in view in fluxing metallic ores are different from the preceding, for the fluxed material or slag is generally worthless. Siliceous is the principal ingredient to be fluxed, and in addition to it the metallic oxides, excepting those which are the prime object of the metallurgical operation. The principal use of fluxing ores is to remove their earthy constituents, and enable the particles of reduced metal to collect in masses; the latter being heavier, will be found at the bottom of the slag. By this removal, also, portions of the metallic oxide which might otherwise escape reduction, are brought under the action of the reducing gases. The melted slag floating on the top of the metal, keeps the latter for a long time in the melted state, until a sufficient quantity has accumulated, and at the same time protects it from the re-oxidizing influence of the air. Another effect of an alkaline flux, such as lime, is due to its stronger basic character than that of the proper metallic oxides, whereby the latter are prevented from uniting with silicic acid, or, if united, are precipitated and reduced.

Principles. Where an ore is reduced the slag should not flow too sluggishly, or otherwise it will hold particles of the metal suspended in it; on the other hand, a too freely-flowing slag may affect the quality of the metal, and, if suffered to flow off too rapidly, may carry a portion of metal with it. Lime is the chief flux used in these operations, because of its cheapness and efficiency; but the pure silicate of lime is rather infusible, and requires a portion of alumina to render the slag sufficiently fusible.

Silicates of potassa and soda fuse readily, and flow freely; those of baryta, strontia and lime fuse with some difficulty, and are sluggish; those of most ordinary metallic oxides resemble the last. It has been found by experience, that, in general, mixed silicates fuse more readily than the simple silicates; thus, silicate of lime fuses and flows freely, if alumina be present; by the formation of the double silicate of lime and alumina, a fact well known in fluxing iron-ores.

An important point in fluxing, is the proportion of flux to the earthy ingredients, which should be such, that while all the latter shall unite with the flux, little or none of that metallic oxide shall be taken up, which is the

main object of the reduction. Thus, in an iron-ore containing silica, alumina, and oxide of iron, if too little lime be employed, a portion of the oxide enters into the slag and is lost; too much lime, on the other hand, makes a less freely-flowing slag, and affects the quality of the metal. If an iron-ore contain only siliceous and oxide of iron, a large amount of lime is rendered necessary, the furnace does not work well, and the iron will be of inferior quality. The admixture of a soft, clayey ore, or of argillaceous limestone, or even clay itself, may be advantageous in such a case; and indeed alumina may then be viewed as constituting the flux, as much as lime. In reducing very clayey iron-ores, and in converting some kinds of pig-metal into bar-iron, siliceous itself is added, and may be called the flux. In this view, a flux is the material or materials wanting to fuse the foreign ingredients in ores.

In fluxing copper-ores, iron pyrites is one of the fluxes, and has a twofold object; 1, to sulphurize all the copper and form a fusible copper-stone (sulphuret of copper and iron); and 2, after its partial oxidation by roasting, to afford oxide of iron as the base for silica to unite with. In afterwards concentrating this stone, which has lost most of its silica but retains much iron, siliceous is added to flux the iron away from the copper. If copper ores contain a large proportion of lime, or if much of the latter be added, the infusible character of sulphuret of calcium imparts more or less infusibility to the silicated slag. This may be avoided by forming sulphate of lime by the roasting process, and then adding fluor spar.

Fluor spar is a valuable flux (whence its name), especially where sulphates are present, with many of which it forms very fusible compounds. The best proportions are about equal equivalents of the spar and the anhydrous sulphates of alkali, lime and oxide of lead; but for the sulphate of baryta, 2 eq. of the spar for 1 eq. of the sulphate. The compounds with sulphates of lime and lead are as fluid as water. Fluor spar likewise assists in fluxing silicates, partly by direct union with them, and partly by yielding fluosilicic gas, and leaving lime to unite with silica.

Special Fluxes. Litharge fuses readily with the oxides of iron, copper, bismuth, antimony and arsenic, sulphate of lead and the silicates, in the proportion of 2 to 5 pts. of litharge to 1 pt. of the substance to be fluxed. Other oxides require a larger quantity of litharge. Its action is that of promoting fusion, reducing an oxide, and desulphurizing a sulphuret. Where silica forms part of the fluxible body, flint-glass is preferable to litharge as a flux.

Black Flux is prepared by deflagrating in an iron vessel a mixture in powder, of 2 pts. crude argal or cream of tartar with 1 pt. nitre, whereby an intimate mixture of carbonate of potassa and fine charcoal is obtained, in which the potash acts by fusing and desulphurizing, and the carbon by deoxidizing. It is especially useful in assays of copper and lead. By employing a smaller proportion of nitre, a larger amount of carbon is obtained. In the above proportion it contains 5 pr. ct. carbon

and 4 pr. ct. carbonate of lime; but with 3 pts. tartar to 1 pt. nitre, it contains 12 pr. ct. carbon and 6 of carbonate of lime. When made, it should be kept in bottles, to prevent its absorbing moisture. An analogous flux may be made by perfectly mingling dry carbonate of soda and charcoal, or instead of the latter starch or sugar. When 2 pts. nitre are deflagrated with 1 pt. argal, *white flux* is formed, consisting of carbonate of potassa with a little lime, and is no better than good pearlash or soda-ash. An important flux for small assays, proposed by Liebig, is the *cyanide of potassium*, which acts powerfully both by reduction and desulphurizing.

Among the simply fusing fluxes, *glass* without lead is conveniently employed; the common window-glass being most fusible, and consisting of silica, lime and soda, or potassa. Bottle-glass is much less fusible, and consists of the same ingredients, with less alkali, but in addition alumina and oxide of iron. In dry assays, one of the most universal fusing fluxes is *borax*, which unites with silica and almost all bases, and is attended with only one disadvantage, its volatility, which prevents an accurate determination of the quantity of matter fluxed.

There are a large number of compound fluxes, formerly employed by metallurgists, which it is scarcely necessary to give; as by an attentive consideration of the principles of fluxing and special fluxes above given, such mixtures may be made, if necessary. For an excellent and detailed view of fluxes, see Berthier's "*Essais par la voie sèche*," t. i., p. 417—520.

FOLIATED TELLURIUM. *Min. Syn.* Pyramidal Tellurium Glance, *M.*, Black Tellurium, *Ph. Ger.* Nagyager Erz, *W.*, Blättertellur, Blättererz. *Fr.* Tellur natif auro-plombifère, *H.*

Descrip. Cryst. Quadratic, showing combinations of 1st and 2d 8-hedra, a 4-sided prism and main end-planes, parallel to which it cleaves perfectly; also granular, particles usually foliated. *H.* = 1 — 1.5; *G.* = 6.84 — 7.22. Color and streak dark lead-gray; metallic; opaque; sectile; flexible in thin laminæ.

Chem. Rel. On charcoal it fumes, coating it yellow, which disappears in the inner flame, tinging it blue, and leaves a globule of malleable gold; in an open tube it fumes, gives off sulphurous acid and forms a white sublimate, which is gray over the test, semifuses, and is tellurate of lead; this distinguishes it from antimonious acid; the white sublimate behaves like oxide. It dissolves in nitric acid, leaving gold, in nitromuriatic, leaving sulphur and chloride of lead, in strong muriatic, leaving AuTe_4 . The analyses of Klaproth and Brande make it PbTe mixed with PbS , and AuTe_3 ; but Berthier's leads to the form. 9PbS , $\text{SbS}_3 + 9\text{PbS}$, AuTe_6 . It occurs at Nagyag and Offenbanya, in Transylvania.

FOOD OF PLANTS. Consists of carbonic acid, ammonia and water, derivatives of the atmosphere, and of earthy, alkaline and metallic salts obtained from the soil. These being transmuted by the vital force of the plant under the influence of light and its appropriate

organism, furnish the elements of the various secretions requisite for the formation or reproduction of the several distinct portions of its structure. The process of assimilation is gradual, but as with animals, the breathing, feeding and digesting of the plant goes on systematically, until the organism is enervated, or the supply of nourishment ceases.

FORMATION. *Geol.* A term applied to a peculiar rock-mass, whether stratified or not, as the Granitic formation, Tertiary formations, &c.

FORMIC ACID. The chief source of the compounds of

FORMYL. The assumed radical of a series of compounds, of which formic acid has been most minutely studied. Sym. $\text{Fo} = \text{C}_2\text{H}$.

1. *Formic Acid.* *Ger.* Ameisensäure. Sym. $\text{FoO}_3 = \text{C}_2\text{HO}_3$, in its anhydrous state. Its name is derived from the ant (*Formica rufa*), from which it was first obtained. Döbereiner first observed its formation from the oxidation of tartaric acid, by binoxide of manganese. It may be obtained by the oxidation of most vegetable bodies, by distilling them with manganese and sulphuric acid, carbonic and sometimes acetic acids being also produced. It is also formed by the oxidation of some vegetable bodies by nitric acid, by the action of strong alkalies and acids on many cyanogen compounds, by the distillation of oxalic acid, &c.

Prep. 1. Crystallized oxalic acid sublimed at between 300° and 320° , retains 1 eq. water, being C_2O_3 , HO or $\text{C}_2\text{H}_2\text{O}_4$; and when it is heated between 338° and 400° , it is decomposed into carbonic acid, water and formic acid, the two last of which equal one-half the weight of the oxalic acid. Two equivalents of the oxalic are thus resolved, $\text{C}_2\text{H}_2\text{O}_8 = \text{C}_2\text{O}_4 + \text{C}_2\text{H}_2\text{O}_4$; which last is hydrated formic acid, C_2HO_3 , HO . (*Schlesinger.*) 2. Immerse red ants in boiling water, and distil them with the same water; oil of ants passes over at the same time. 3. Mix in a retort equal measures of water, oil of vitriol and rye grain, heat to boiling, collect the distilling water, and when the grain blackens, pour back the distillate and so much water as to make up the original volume of mixture; distil off about as much as the last, which is then strong formic acid; add as much more water to the retort, and distil again to obtain a weaker acid, which towards the last is adulterated with sulphurous acid. (*Emmet.*) 4. Add 3 pts. binoxide of manganese in a retort to a solution of 1 pt. sugar in 2 pts. water, heat to 140° , and add gradually 3 pts. oil of vitriol, previously diluted with an equal volume of water; when the foaming has ceased, distil to dryness. It yields 5 pts. formic acid of 1.02 spec. grav., 100 pts. of which saturate 7.13 pts. dry carbonate of soda. (*Döbereiner.*) 5. It is conveniently and economically prepared in a copper still, which should be 15 times as capacious as the volume of mixture, by mixing 4 pts. manganese, 1 pt. starch and 4 pts. water, and then gradually 4 pts. oil of vitriol, with constant stirring; heat rapidly until the mixture puffs, put on the head, and distil off $4\frac{1}{2}$ pts. of liquid. This acid has 1.025 spec. grav., and 100 pts. saturate 10.6 pts. dry carbonate of soda. For

smaller operations, the quantity of water must be diminished. *Liebig.*

To purify the crude acid, saturate it with carbonate of lime, adding some milk of lime to decompose the acid sulphite of lime; filter, evaporate the formiate of lime to dryness, decompose 10 pts. of this salt with 8 pts. oil of vitriol diluted with 4 pts. water, and distil in a sand-bath. It yields 9 pts. strong formic acid, of 1.075 spec. grav. To obtain it still stronger, dilute the 8 pts. acid with $1\frac{1}{2}$ pts. water. The strongest acid obtained by this method is procured by distilling, in a bath of chloride of calcium, 18 pts. finely powdered formiate of lead, with 1 pt. water and 6 pts. oil of vitriol. This acid contains only 2 eq. water, is as corrosive as the monohydrate, has a spec. grav. = 1.1104, boils at 223° and its vapor is inflammable. To obtain the simple hydrated acid, pulverize finely formiate of lead, dry it at 266° or over oil of vitriol, introduce it into a tubulated retort or a $\frac{1}{2}$ -inch broad glass tube, the beak or end of which is drawn out, and passed into a small receiver; pass over it dried sulphuretted hydrogen until all the lead-salt is decomposed, drive the acid into the recipient by gentle warmth, and boil it once, to free it from sulphuretted hydrogen. PbO , $\text{FoO}_3 + \text{HS} = \text{PbS} + \text{FoO}_3$, HO . *Liebig.*

Prop. The simple hydrate is a clear and colorless liquid, fuming slightly in the air, of an extremely penetrating odor, of spec. grav. 1.2353, having about the same boiling and freezing points as water, its vapor burning with a blue flame, crystallizing at 33.8° in broad, shining laminae. It is exceedingly caustic, a single drop on the skin producing violent pain, and a very painful wound. It is miscible with water without heating, and warmed with alcohol it yields formic ether. Heated with an excess of concentrated sulphuric acid, it is decomposed with lively effervescence into carbonic oxide and water, the latter of which remains with the acid; C_2HO_3 , $\text{HO} + \text{SO}_3$, $\text{HO} = \text{C}_2\text{O}_2 + \text{SO}_3$, 3HO . Heated with oxide of mercury or silver, or with their oxy-salts, it is resolved into carbonic acid, and the oxide reduced to metal; $\text{C}_2\text{H}_2\text{O}_4 + 2\text{HgO} = \text{C}_2\text{O}_4 + 2\text{HO} + \text{Hg}_2$. This behavior adapts those oxides to the analysis of compounds containing formic and acetic acids.

Formic acid is separated from oxalic, tartaric and racemic acids by boiling with carbonate of lime, which precipitates them; the very dilute solution is then precipitated with neutral acetate of lead, to separate malic acid; the solution now concentrated by evaporation, and mixed with alcohol, which precipitates formiate of lead, and keeps the acetate in solution.

Formiates. The affinity of this acid for bases is strong, and its salts are formed by dissolving metallic oxide, hydrated or carbonated in the acid, all being soluble in it. The dry alkaline formiates are decomposed by heat into carbonates, combustible gases being given off; the formiates of the heavy basic metals by heat, give off carbonic acid, carburetted hydrogen and water, and leave carbon with the metal or oxide. Formiate of *potassa* is very soluble, crystallizing with difficulty; that of *soda* crystallizes in rhombic prisms,

very soluble in water, deliquescent, insoluble in alcohol, is a convenient reagent to reduce the precious metals in solution. The *ammoniacal* salt is crystallizable, deliquescent, and decomposes by rapid heat into prussic acid and water; $\text{NH}_4\text{O}, \text{C}_2\text{HO}_3 = \text{C}_2\text{N}, \text{H} + 4\text{HO}$. The salt of *baryta* forms transparent, lustrous prisms, inalterable in air, soluble in 4 pts. water, insoluble in alcohol; that of *strontia* 6-sided prisms of the form. $\text{SrO}, \text{FoO}_3 + 4\text{HO}$; that of *lime* forms similar but small prisms, soluble in 10 pts. water, not in alcohol; that of *magnesia* forms persistent needles, soluble in 13 pts. water, not in alcohol. The salt of *alumina*, formed by double decomposition, is very deliquescent, difficult to crystallize, and becomes clouded by heating its solution. The salts of protoxides of *iron* and *manganese*, of oxides of *zinc*, *nickel*, *cobalt*, *cadmium* and *copper*, are very soluble and crystallizable; the salt of *lead* is soluble in 36 to 40 pts. of water, and forms a basic salt, by digestion with litharge; the salt of *silver* is sparingly soluble; formiate of red oxide of *mercury* is easily formed by direct solution in the cold; but by the slightest heat applied to it, either dry or in solution, it is resolved, with the escape of carbonic acid, into the salt of the suboxide, which by a little higher heat is in its turn decomposed, and deposits metallic mercury. The *cerium* salt is the most insoluble of all. In its behavior to lead and alumina, formic closely resembles acetic acid.

Formic ether, $\text{EO}, \text{FoO}_3 = \text{C}_6\text{H}_5\text{O}_4$, is obtained by distilling 7 pts. dry formiate of soda with 10 pts. oil of vitriol and 6 pts. alcohol (of 90 pr. ct.), and is a limpid liquid of a strong, aromatic odor and taste; spec. grav. 0.912; boiling at 128° ; soluble in 10 pts. water. *Formic mether*, from wood spirit, has an odor similar to acetic ether, and boils at about 100° .

Oil of Ants. $\text{C}_2\text{H}_2\text{O}_2$. Distil equal weights of oatmeal or sawdust with sulphuric acid, diluted with an equal bulk of water. When pure its taste and odor are aromatic, resembling oil of cloves; spec. grav. 1.1006; boils at 334.4° , burns with a yellow flame, is soluble in water, but more so in alcohol and ether. *Stenhouse*.

2. Formyl and Chlorine. By exposing alcohol, ether and wood-spirit, and some salts of ether to the action of chlorine, several compounds of this element, with formyl, are obtained.

1. Protochloride of Formyl. C_2HCl or FoCl . Obtained by dissolving perchloride of acetyl in alcohol containing potassa, and distilling the clear liquor after the deposition of chloride of potassium; $\text{C}_4\text{H}_3\text{Cl}_3 + \text{KO} = 2(\text{C}_2\text{HCl}) + \text{HO} + \text{KCl}$. It is an oily liquid, heavier than water, boiling between 86° and 104° , its vapor has the spec. grav. 33.21, insoluble in water, soluble in alcohol and ether. (*Regnault*.) Berzelius regards *Chloral* as a compound of chloride of formyl and chloro-carbonic acid; thus chloral, $\text{C}_4\text{HCl}_3\text{O}_2 = \text{C}_2\text{HCl} + 2\text{CClO}$. **2. Bichloride of Formyl.** C_2HCl_2 or FoCl_2 . Obtained by passing chlorine into chloride of eläyl as long as muriatic acid passes off, and gently warming the liquid towards the last; by washing with water,

drying and distilling over mercury, the middle third of the distillation is the pure compound. *Regnault* prepares it from perchloride of acetyl. It is a colorless, oily liquid, of 1.576 spec. grav.; boiling at 275° , its vapor has a spec. grav. = 5.796; it is insoluble in water, soluble in alcohol and ether; decomposed by caustic potassa. (*Laurent*.) **3. Parabichloride of Formyl** is obtained, like 2, from paraperchloride of acetyl, and is an oily liquid of ethereal odor; spec. grav. 1.53; boiling at 222° ; decomposed with difficulty by alkalies. (*Regnault*.) **4. Perchloride of Formyl.** $\text{C}_2\text{H}, \text{Cl}_3$. See *Chloroform*.

By the action of chlorine upon gaseous mether, *Regnault* obtained the bichlorinated oxide of methyl, which Berzelius terms Formyl-aci-bichlorid, and considers as composed of 1 eq. formic acid and 2 eq. chloroform; $\text{FoO}_3 + 2\text{FoCl}_3 = \text{C}_6\text{H}_3\text{Cl}_6\text{O}_3$. *Regnault's* formula is $\text{C}_2\text{HCl}_2\text{O}$, on the theory of substitution.

3. Bromine forms a similar series of compounds to chlorine, but they have been less studied. Bromal is similar to chloral, and may be viewed as bromide of formyl, with bromo-carbonic acid. See *Bromal*. Bromoform or *perbromide of formyl* is obtained by treating bromal with potassa, or better by saturating lime with bromine (as in preparing chloroform), mixing with alcohol and distilling. It is closely allied to chloroform in all its properties, but has the spec. grav. 2.10, and a higher boiling point; form. FoBr_3 . *Löwig*.

4. Periodide of Formyl. Iodoform, FoI_3 . Saturate alcohol with iodine, and add, dropwise, to it tincture of potassa with constant stirring, stopping the addition precisely when the liquid is discolored; water is then added as long as a precipitate appears, or the liquid is gently evaporated when the iodide deposits in crystals, which are freed from iodide of potassa by washing with water, redissolved in alcohol or ether, and allowed to crystallize by spontaneous evaporation. It forms brilliant lemon-yellow, 6-sided laminæ, of a saffron odor and sweetish, aromatic taste; spec. grav. about 2.0; fuses, and may be sublimed at 212° , but decomposes between 239° and 248° into iodine, iodohydric acid and charcoal; insoluble in water, readily soluble in alcohol and ether; tincture of potassa decomposes it into formiate and iodohydrate of potassa. By distilling a mixture of iodoform and perchloride of phosphorus, mixing the red distillate with oil of vitriol and redistilling, the yellow distillate now obtained is closely allied to iodoform in properties, and has the composition $\text{FoI}_3 + 2\text{FoCl}_3$. By adding a sufficient quantity of bromine to iodoform, and adding an aqueous solution of potassa, iodide of bromine is dissolved, and the remaining yellow, oily liquid is $\text{FoBr}_3 + 2\text{FoI}_3$. By distilling Prussian blue with chloride of lime, *Bonnet* inferred that he obtained a cyanide of formyl.

5. Trisulphuret of Formyl. FoS_3 . Obtained by distilling 1 pt. iodoform with 3 pts. finely powdered vermilion; $\text{FoI}_3 + 3\text{HgS} = \text{FoS}_3 + 3\text{HgI}$; the yellow iodide of mercury sublimes, and the sulphuret of formyl distills over. It is a yellow, oily liquid, with an aromatic and hepatic odor, a sweetish, ethereal taste; is insoluble in water, readily soluble in

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alcohol and ether; is decomposed by potassa into formiate of potassa and sulphuret of potassium. *Bouchardat.*

FORMULA. *Chem. Min.* A formula is a condensed expression for the composition of a body. One equivalent of each element is expressed by one or two letters, which are the initial and characteristic letters of their Latin names. Thus, N signifies nitrogen, Na sodium, or in Latin, natrium. See **ELEMENTS**, for these symbols. A few compound bodies, chiefly organic, are also expressed by symbols: thus,

+

Cy = cyanogen, A = acetic acid, M = morphin, &c. A small figure following the symbol expresses the number of equivalents of the element, and may be placed above or below, thus: C² or C₂, signifies two equivalents of carbon. In binary and in complex organic compounds, the symbols are placed side by side, and the more electro-positive usually on the left hand, thus: HO = water, or 1 eq. of hydrogen and 1 eq. oxygen; SO₃ = sulphuric acid. In organic bodies composed of hydrogen, carbon, and oxygen, carbon is always placed on the left and oxygen on the right, thus: C₄H₂O₃ = A = acetic acid, which is composed of 4 eq. carbon, 3 eq. hydrogen and 3 eq. oxygen. When nitrogen forms also a part of the compound, its symbol is sometimes placed next to the oxygen, sometimes adjoining the carbon, thus: C₄₀H₃₁N₅O₁₂, or C₄₀N₅H₃₁O₁₂ = protein; but the former is more generally adopted. The number of equivalents of a binary compound is expressed by a large figure placed before the symbols, thus: 3 HO = 3 eq. water, 2 CO₂ = 2 eq. carbonic acid.

Oxygen and sulphur forming extended classes of compounds, Berzelius designates an equivalent of the former by a dot, and of the latter by a comma or dash placed over the symbol of another element, thus: Ḣ = HO = water, H̄ = HS = sulphuretted hydrogen, S̄ = SO₃ = sulphuric acid, As = AsS₃ = tersulphuret of arsenic or orpiment. Since many binary compounds exist composed of 2 eq. of one element and more than two of another, Berzelius employed type with a dash through the initial letter of the symbol, which others represent by a dash below that letter, or by a heavy type from a different font, thus: $\overline{\text{Al}}$ = $\overline{\text{Al}}$ = Al₂O₃ = alumina.

Since one great advantage of a formula is to present the most condensed view of a compound, a picture to the eye, Berzelius' notation is unquestionably superior to every other; but the cost of having a font of type expressly for chemical works, has induced the majority of chemists to employ the algebraic notation. Where Berzelius' formulas are employed, a small figure after a symbol not only multiplies the literal symbol, but the whole symbol; thus, in K²S₂, Ḣ, or bisulphate of potassa, the small 2 does not simply mean 2 eq. sulphur, but 2 eq. sulphuric acid.

In ternary and higher compounds, the ele-

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ments are arranged in groups expressing the theoretic view of their mode of combination; thus, carbonate of lime has a composition expressed by C CaO₃, or 1 eq. carbon, 1 eq. calcium and 3 eq. oxygen; but as we believe the carbon to be united with 2 eq. oxygen, forming carbonic acid, and the calcium with 1 eq. oxygen, forming lime, it is written CaO, CO₂, or CaO + CO₂. The empirical formula of copperas, FeH₇SO₁₁, conveys a very imperfect knowledge of its composition compared with FeO, SO₃ + 7 HO. A comma is generally used to separate a compound from an element or other compound, both of which are essential, and the sign + to separate that portion from the rest which is less essential, as in the preceding formula of copperas, where the 7 HO expresses water, which is partly or wholly water of crystallization. The sign + is also used to separate two ternary compounds from each other, in bodies of complex constitution; thus, the mineral gay-lussite is composed of 1 eq. soda, 1 lime, 2 carbonic acid and 5 water, and is written NaO, CO₂ + CaO, CO₂ + 5 HO. A large figure multiplies the whole formula to the first +, or comma, or when placed before a parenthesis, the whole compound embraced in the parenthesis. A parenthesis is often conveniently employed in complex compounds; thus, bicarbonate of potassa is written KO, 2 CO₂ + HO; alum is written KO, SO₃ + Al₂O₃, 3 SO₃ + 24 HO, or (KO + SO₃) + (Al₂O₃ + 3 SO₃) + 24 HO; humboldtite = 2 (FeO, C₂O₃) + 3 HO, or 2 eq. oxalate of iron and 3 eq. water; light ruby silver = 3 AgS, AsS₃, where the large 3 only signifies 3 eq. of sulphuret of silver. The advantage of Berzelius' notation will be evident by comparing the above with his formula for alum: KO, SO₃

+ Al₂O₃, 3 SO₃ + 24 HO = K²S̄, $\overline{\text{Al}}$ S̄³ + H²⁴.

Silicic acid combines in numerous proportions with bases, examples of which are furnished chiefly by minerals, and hence reference is made to *Silicates*, under **SILICIUM**.

Isomorphous bases and acids frequently replace each other; and where many of these bases occur together, as is frequently the case among minerals, their formula, fully written out, would lose the great advantage of condensation. To obviate this, it is not uncommon to write the bases under each other; thus, feldspar often contains soda and lime in addition to its potassa, and sesquioxide of iron, together with alumina, when its formula may be ex-

pressed by $\left. \begin{matrix} \text{KO} \\ \text{NaO} \\ \text{CaO} \end{matrix} \right\} \text{SiO}_3 + \left. \begin{matrix} \text{Al}_2\text{O}_3 \\ \text{Fe}_2\text{O}_3 \end{matrix} \right\} 3 \text{SiO}_3$.

But since this does not express any proportion between the isomorphous bases, proportional numbers have been sometimes prefixed to them. A far better method, however, is to include all these bases under some arbitrary symbol, such as RO or R₂O₃, R being the sign of radical or basis. RO might then express lime, magnesia, protoxides of iron and manganese, oxide of copper, &c., or baryta, strontia, oxide of lead, &c., and R₂O₃ would stand for alumina, sesquioxides of iron and chrome, &c. See **ISOMORPHISM**. The advantage of this notation will be apparent from a few examples.

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GARNET contains silicic acid, sesquioxide of iron and alumina, lime, magnesia and protoxides of iron and manganese; and to give a separate formula for each variety, would be useless and uninformative, or even to write all like bases under each other; but it presents a clearer view of its composition to write 3RO , $\text{SiO}_3 + \text{R}_2\text{O}_3$, SiO_3 , and then to state that RO or R_2O_3 represents particular bases, and in what proportion, if necessary. It is by this means that several mineral species, separated by reference to their external characters alone, may be brought together under one species, as in fact they should be. Thus, in the table of FELSPATHIC minerals, Albite and Feldspar are brought together under the general formula RO , $\text{SiO}_3 + \text{R}_2\text{O}_3$, 3SiO_3 , from which it would appear that potassa and soda are both isomorphous and dimorphous. Magnetic iron has the composition FeO , Fe_2O_3 ; Chromic iron FeO , Cr_2O_3 ; Gahnite ZnO , Al_2O_3 , including magnesia and protoxide of iron, under the oxide of zinc; Franklinit and Dysluite are still more complex; yet all these minerals may and should be embraced under the general formula RO , R_2O_3 ; and we might include Hausmannite, MnO , Mn_2O_3 , Pitchblende, UO , U_2O_3 , and perhaps several others under the same.

No discovery in chemistry has advanced the science further and more rapidly than the invention of formulæ, instead of the percentage expression of composition formerly used; as they convey to the eye, like a picture, a far clearer view of chemical composition than the

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most labored description could effect. But since much of their value depends upon the facility with which a well-known symbol represents a particular element, any interference with these established symbols is a matter of regret to every sound chemist, and should at once be discountenanced. An innovator may gratify his vanity, and impose on a few, at the expense of his solid reputation.

The complex nature of organic bodies, their great number and variety, the slight differences of constitution with very different properties, and the isomeric composition of many similar and dissimilar bodies, while they render formulas essential to present them to the mind, yet require a classification of these formulas, which shall bring together those bodies which are evidently allied to each other. Such arrangements have been adopted, but have not been followed because of their imperfections, due in some measure to the transitory character of organic formulas. Gerhardt has made a fair attempt at such a classification, by ranging bodies in families according to the number of their equivalents of carbon; thus, the 1st family contains 1 eq. carbon, the 5th family 5 eq. of carbon, &c. Each family is subdivided according to the quantity of oxygen; thus, CH_2O_2 would belong to the 1st family and 2d division. The families being arranged in horizontal lines, vertical columns express the proportion of hydrogen. The following view of the 4th family will illustrate his system, it being observed that he writes H_2 for our equivalent H .

Family.	General Formula.	$\text{R} + ^2$	R	$\text{R} - ^2$	$\text{R} - ^4$	$\text{R} - ^6$
4.	R}	.....	\text{C_4H_8 Quadricarb. of Faraday.			
	RO	$\text{C}_4\text{H}_{10}\text{O}$ Ether.				
	RO_2$	.....	\text{C}_4\text{H}_8\text{O}_2$ Butyric acid.			
	RO_3	$\text{C}_4\text{H}_{10}\text{O}_3$ Formone- thylal.	.....	.....	$\text{C}_4\text{H}_4\text{O}_3$ Succinic acid, anhyd.	
	RO_4$	.....	.....	\text{C}_4\text{H}_6\text{O}_4$ Succinic acid.	$\text{C}_4\text{H}_4\text{O}_4$ Fumaric and Maleic acid.	$\text{C}_4\text{H}_2\text{O}_4$ Mellitic acid.
	RO_5$	.....	.....	\text{C}_4\text{H}_6\text{O}_5$ Malic acid.	$\text{C}_4\text{H}_4\text{O}_5$ Tartaric acid, anhyd.	
	RO_6$	.....	.....	\text{C}_4\text{H}_6\text{O}_6$ Tartaric acid.		

Column R contains the radical C_4H_8 , and its oxide, butyric acid; $\text{R} + ^2$ signifies the radical with 2 more of hydrogen; $\text{R} - ^2$ the radical with 2 less of hydrogen, &c. The attempt to arrange bodies in this manner is premature, since many formulas are not positively determined, and bodies are not classified according to their alliances.

The researches of modern chemistry have shown that many essential oils have the for-

mula C_5H_8 , or a multiple of it, as oils of juniper, savine, lemons, pepper, &c. = C_5H_8 , of oranges C_{10}H_8 , of cubebs $\text{C}_{15}\text{H}_{12}$, of terpen-
tine $\text{C}_{20}\text{A}_{16}$; hence a general formula, mC_4H_4 , may be adopted for this class of bodies. Farther investigation will also give a general formula for camphors and other essential oils. By comparing the formulas of many fat acids, a remarkable relation is observed between them; thus, in hydrated butyric acid $\text{C}_4\text{H}_8\text{O}_4$,

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caprylic acid $C_{16}H_{16}O_4$, margaric acid $C_{34}H_{34}O_4$, &c., for the same quantity of oxygen; the quantities of carbon and hydrogen are very different, but their proportions the same. Since these last proportions are the same and also equal, we may assume as the radical of this series of bodies, CH , united always with O_4 , so that butyric acid would be represented by R_8O_4 , caprylic by $R_{16}O_4$, margaric by $R_{34}O_4$, &c., and their general formula would be R_nO_4 . If we assume these acids to be anhydrous, then the general formula might be $C_nH_{n-1}O_3$ (the above dry acids being $C_8H_7O_3$, $C_{16}H_{15}O_3$ and $C_{34}H_{33}O_3$). But as the bodies CH and C_2H are generated by the dry distillation of these fatty bodies, we may call CH etherole = E , and C_2H benzin, = B ; and while the latter exists only in 1 proportion in all these acids, the E is variable. In this view, the general formula of the fat acids would be E_nBO_3 , the special formula of butyric acid

E_6BO_3 , of margaric $E_{32}BO_3$, &c. The former $C_nH_{n-1}O_3$ is the empirical, the latter, E_nBO_3 , the rational formula, as it assumes to explain the mode of combination. But in the present changing state of the science, a rational formula of this kind is not likely to be adopted. For a single family of allied bodies, the carbon and hydrogen may be thrown together as the radical; thus, $C_nH_{n-1} = R$ of the dry, fat acids, whose general formula would be R_nO_3 ; but when we consider their aldehydes, ethers, &c., the same R could not be used, for the R of aldehyde should be C_nH_n , and of ether C_nH_{n+1} . It is therefore better to adopt simple empirical formulas for each family of allied bodies. The following table of alcohols, ethers, aldehydes, anhydrous acids and acetones, will illustrate these views. The series is named by that of the acids, which are more fully known.

	Alcohols. $C_nH_{n+2}O_2$	Ethers. $C_nH_{n+1}O$	Aldehydes. $C_nH_nO_2$	Acids. $C_nH_{n-1}O_3$	Acetones. C_nH_nO
Formic	$C_2H_4O_2$	C_2H_3O	$C_2H_4O_2$	$C_2H_3O_3$	
Acetic	$C_4H_6O_2$	C_4H_5O	$C_4H_4O_2$	$C_4H_3O_3$	C_3H_3O
Butyric	$C_8H_{10}O_2$	C_8H_9O	$C_8H_8O_2$	$C_8H_7O_3$	C_7H_7O
Valerianic	$C_{10}H_{12}O_2$	$C_{10}H_{11}O$	$C_{10}H_{10}O_2$	$C_{10}H_9O_3$	C_9H_9O
Caproic				$C_{12}H_{11}O_3$	
Enanthylic			$C_{14}H_{14}O_2$	$C_{14}H_{13}O_3$	
Caprylic				$C_{16}H_{15}O_3$	
Pelargonic				$C_{18}H_{17}O_3$	
Ceraic				$C_{20}H_{19}O_3$	
Cocinic				$C_{26}H_{25}O_3$	
Myristic				$C_{28}H_{27}O_3$	
Cetylic }	$C_{32}H_{34}O_2$	$C_{32}H_{33}O$		$C_{32}H_{31}O_3$	
Palmitic }					
Margaric				$C_{34}H_{33}O_3$	$C_{33}H_{33}O$

To the alcohol list we might add cerosin, $C_{48}H_{50}O_2$, but its transformations have not been studied. Cetylic ether is only known in composition. The butyric, valeric and enanthylic aldehydes are severally known as butyral, valeral and enanthal. The general formula $C_nH_{n-2}O_3$, embraces succinic, suberic and sebacic acids; $C_nH_{n-3}O_3$ includes fumaric, aconitic, itaconic, citraconic, acrylic, phoenic, camphoric, campholic and elaidic acids; $C_nH_{n-9}O_3$, salicylous, benzoic, caryophyllic and cuminic acids. In like manner $C_nH_nO_n$ expresses the composition of fibre, starch, gum, sugar, &c. Such general formulas will be found useful and convenient; and when the science is farther advanced, they can be substituted by rational formulas, which are equally expressive of composition, and more so of character.

FORSTERITE. *Min.* Cryst. Right rhombic, the 8-hedron sometimes large; cleaves readily parallel to main end-plane. $H. = 7.5$. Colorless, translucent, vitreous, splendent. Its composition is unknown, farther than it contains silica and magnesia. Local. Vesuvius.

FOSSIL. *Min. Geol.* From the Latin, signifying *dug*, was formerly applied to all mineral substances dug out of the earth; but is now restricted to mineral organic remains, whether casts, shells, bones or excrements. It is often used as an adjective, as fossil

bones, &c., and is then applied also to coal, as fossil fuel.

FOSSIL COPAL. See **COPALITE**.

FOUSEL OIL. When inferior French brandies are concentrated, it remains in the still, partly separated and separable by water. (*Ballard.*) By distillation the oil passes over between 266° and 284° , admixed with a little enanthic ether. This latter is removed by caustic potassa and redistillation at 269.6 . The product is a pure amylic alcohol, and can also be obtained during the distillation of other alcoholic liquors. See **AMYL**.

FOWLERITE. See **MANGANESE SPAR**.

FRACTURE. *Min.* Crystallized bodies generally cleave in certain directions with plane surfaces; but when they or amorphous minerals are broken in other directions, the peculiarity of the fractured surface is often a convenient mean of determining and describing them, as it is remarkably uniform in the same body. A fractured surface, or simply the fracture, is *conchoidal* (shell-like) when the surface is concave or convex; *even* when it is nearly flat; *uneven* when it is rough, and *hackly* when it is very jagged, or sometimes splintery. See *Cleavage*, under **CRYSTALLOGRAPHY**.

FRANKINCENSE. See **OLIBANUM**.

FRANKLINITE. *Min. Descrip.* Cryst. Regular, usually the 8-hedron alone or combined with the 12-hedron, and rarely the 24-

hedron; cleavage 8-hedral, indistinct. Also massive, coarse or fine granular, particles strongly coherent. $H. = 5.5 - 6.5$, $G. = 4.87 - 5.09$. Iron-black, metallic, opaque; brittle, with conchoidal fracture and dark, reddish-brown streak; acts slightly on the magnet.

Chem. Rel. Infusible, but coating the charcoal with zinc-smoke, especially by addition of soda; shows oxides of iron and manganese in borax; gives manganese with soda, on platinum foil. Dissolves wholly in warm chlorohydric acid, evolving chlorine to a greenish-yellow liquid; decomposed readily by fusion, with bisulphate of potassa.

Probable formula, $\text{FeO} \left\{ \begin{array}{l} \text{Fe}_2\text{O}_3 \\ \text{ZnO} \end{array} \right\} \left\{ \begin{array}{l} \text{Fe}_2\text{O}_3 \\ \text{Mn}_2\text{O}_3 \end{array} \right\}$, or $\text{RO} \cdot \text{R}_2\text{O}_3$, which is the general formula of magnetic and Chromic iron, Dysluite and Spinell, with which it is isomorphous. It contains 10 to 12 pr. ct. zinc, and Abich found a trace of cadmium in it. Kobell and Rammelsberg think that the formula is incorrect; but by calculation from Abich's analysis, the 10.81 pr. ct. oxide of zinc will take up the 18.17 pr. ct. sesquioxide of manganese, and the 0.73 alumina, together with a little peroxide of iron; and if from the 66.88 peroxide of iron we abstract the last, and calculate the remainder as magnetic oxide, the protoxide of iron in it would require about 2 pr. ct. oxygen to convert it into peroxide, or only a little more than the oxide of manganese can give off by solution. The chlorine which franklinite would give off by solution in muriatic acid, tends to convert the protoxide into peroxide of iron; but not doing it effectually, some chlorine is actually given off, and Kobell detected small quantities of protoxide of iron in the solution. The probability therefore is, that the formula above given is correct; and it is certainly much strengthened by the isomorphs of franklinite. See *DYSLUITE*, for an associated mineral.

Local. Franklinite abounds at Hamburg, N. Jersey, near the Franklin Furnace, associated with Red zinc-ore; and at Sterling, in the same vicinity, associated with Troostite. It also occurs near Aix-la-Chapelle. The mixed ore of franklinite and red zinc has been unsuccessfully worked for metallic zinc; but there appear to be no good chemical grounds for abandoning the attempt, while its great abundance should offer the strongest inducements to attempt its distillation.

FRAXIUM. The bitter principle of the *Fraxium excelsior*. Crystallizes in delicate 6-sided prisms, and is soluble in water and alcohol.

FREEZING. See **HEAT.**

FREEZING MIXTURES. When a solid is converted into a liquid without the application of heat, the heat necessary for liquidity is abstracted from surrounding bodies and cold results. The degree of cold varies with the substances liquefied, and no general law has yet been found for determining it. Nearly all crystallized salts diminish the temperature by solution in water; by mixing some salts while dissolving, a greater degree of cold is produced. On the other hand many dehydrated salts, such as sulphate of soda, raise the tem-

perature by combining with water. The common mode of expressing this difference is, that when water combines chemically with a salt, heat is evolved; when otherwise, cold is produced; this may be regarded as correct, if viewed simply as the expression of a fact; for our knowledge on the subject is too imperfect to advance a theory as to what amount of water is chemically combined or constitutional water, and what is united by other attraction. By the use of dilute acid with a salt, a greater degree of cold is produced, and still more by the use of snow or pounded ice, instead of water.

The following tables, by Walker, show the degree of cold produced by different mixtures, the 1st being mixtures with water, the 2d with snow or pounded ice.

Mixtures.	Pts.	Thermom. sinks from	to	Deg. of cold.
Nitrate of ammonia..	1	}	+50° +4°	46°
Water	1			
Muriate of ammonia.	5			
Nitrate of potash ...	5	}	+50° +10°	40°
Water	16			
Sulphate of soda.....	3			
Diluted nitric acid...	2	}	+50° -3°	53°
Sulphate of soda.....	6			
Muriate of ammonia.	4			
Nitrate of potash	2	}	+50° -10°	60°
Diluted nitric acid...	4			
Sulphate of soda.....	6			
Nitrate of ammonia..	5	}	50° -14°	64°
Diluted nitric acid...	4			
Sulphate of soda.....	8			
Muriatic acid.....	5	}	+50° 0°	50°
Phosphate of soda ...	5			
Nitrate of ammonia..	3			
Diluted nitric acid...	4	}	0° -34°	34°
Snow or pounded ice.	2			
Common salt	1	}	any temperature.	-5° *
Snow or pounded ice.	5			
Common salt	2			-12° *
Sal ammoniac.....	1			
Snow or pounded ice.	24			-18° *
Common salt.....	10			
Sal ammoniac.....	5			-25° *
Nitrate of potash	5			
Snow or pounded ice.	12			+32° -30° 60°
Common salt	5			
Nitrate of ammonia..	5	}	+32° -30°	60°
Snow.....	7			
Diluted nitric acid...	4	}	+32° -50°	82°
Snow.....	2			
Cryst. muriate of lime	3	}	+32° -51°	83°
Snow.....	3			
Potash	4	}	0° -46°	46°
Snow.....	3			
Diluted nitric acid...	2	}	0° -66°	66°
Snow.....	1			
Cryst. muriate of lime	2	}	-66° -91°	25°
Snow.....	8			
Diluted sulphuric acid	10	}		

The following table, by Karsten, shows the diminution of temperature in degrees, Fahr., where 1 pt. of a salt is dissolved in 4 pts. water:—

FREEZING MIXTURES.

Salts.	Degrees of cold.
Nitrate of lead.....	3·4°
“ baryta	3·8°
Common salt	3·8°
Sulphate of copper.....	4·0°
“ potassa	5·2°
“ zinc	5·6°
“ magnesia	8·1°
Muriate of baryta	8·1°
Sulphate of soda	14·6°
Nitrate of soda	17·0°
“ potassa	19·1°
Chloride of potassium.....	21·3°
Nitrate of ammonia	25·4°
Muriate of ammonia	27·3°

The following table, also by Karsten, shows the degrees of cold produced by dissolving 1 pt. of a salt in 4 pts. of a saturated solution of another salt:—

Salts.	Sat. solution of	Degrees of cold.
Salammoniac	Common salt	15·1°
“	Saltpeter.....	22·7°
Saltpeter.....	Salammoniac	17·5°
“	Common salt	16·9°
“	Nitrate of soda.....	12·7°
“	“ baryta.....	17·5°
“	“ lead.....	17·1°
Glauber's salt....	Common salt	8·5°
Common salt	Blue vitriol	7·4°
Nitrate of soda...	Salammoniac	16·4°
“	Saltpeter.....	16·6°
“	Common salt	14·0°
“	Muriate of baryta..	4·9°
“	Nitrate of lead.....	14·4°
Nitrate of baryta.	Saltpeter.....	1·35°
Sulphate of zinc..	Sulphate of potassa.	3·1°

The following table, by Karsten, of 1 pt. salt in 4 pts. of a saturated solution, show an increase of temperature:—

Salts.	Sat. solution of	Degrees of heat.
Common salt	Salammoniac	8·2°
“	Glauber's salt.....	3·1°
“	Saltpeter.....	1·35°
“	Nitrate of soda	6·8°
Muriate of baryta..	“	1·15°

By mingling solid lead amalgam with solid bismuth amalgam, whereby they become liquid, Orioli obtained 39·6° of cold. Döbereiner mixed 204 pts. lead-amalgam (103 lead, + 101 mercury) with 172 pts. bismuth amalgam (71 bismuth + 101 mercury), and obtained a diminution of from 68° to 30·2°; and by adding to the same 202 pts. more of mercury, the temperature fell to 17·6°. By dissolving the powders of 59 pts. tin, 103·5 pts. lead and 182 pts. bismuth, in 808 pts. mercury, the thermometer falls from 63·5° to 14°.

Two liquids mingled rarely produce cold, although it may take place even where there is a condensation. By mixing 44 pts. of a concentrated solution of nitrate of ammonia (of spec. grav. 1·302) with 34 pts. water at 60·8°, the mixture cools 9°, and has a density of 1·159, although the mean density is 1·151. A saturated solution of saltpeter gives, with a

FRENCH BERRIES.

sat. solution of nitrate of soda, an increased heat of 0·11°; but by adding an equal weight of water to the mixture, it produces 2·45° of cold. Equal quantities of saturated solutions of chloride of barium and sulphate of zinc cool 3·6°; of salammoniac with excess of blue vitriol, cool 2·88°, while with excess of salammoniac, 2·88° of heat is produced.

Economical mixtures for producing ice are 4 pts. of a cooled mixture of 50 oil of vitriol and 55 water, with 5 pts. Glauber's salt; 9 pts. muriatic acid (of 15° Beaumé) with 14 Glauber's salt. Somewhat varying proportions may be followed. According to Bischof and Wöllner, the greatest cold of such a mixture is attained by 50 pts. oil of vitriol, 33 pts. water and 104 Glauber's salt, which depresses the thermometer 49½°.

FRENCH BERRIES. “The berries of the different species of *Rhamnus* are very much used for dyeing, under the names of *French*, *Spanish*, *Turkey* and *Persian* berries. According to M. Chevreul, they yield to water, amongst other bodies—1. A yellow coloring principle, which is united with a substance insoluble in ether, sparingly soluble in concentrated alcohol, and very soluble in water. It appears to be very volatile. 2. A matter remarkable from its intense bitterness, and which is soluble in water and in alcohol. 3. A red principle which exists only in small quantity, and which decomposes into a brown substance under the influence of air. It is principally found in the residue of the aqueous extract of the berries, and is insoluble in ether and alcohol.

“Persian berries of excellent quality were bruised in a mortar, and then treated with ether, which acquired an olive-yellow color. The liquor was evaporated in a retort to two-thirds, and the residue mixed with water, which became of a dark-yellow color. Some hydrate of lead, added in small quantity, precipitated a brown-yellow lake; fresh hydrate added to the filtered liquid, then gave a beautiful lake of very vivid yellow. This last was decomposed by sulphuretted hydrogen. The filtered liquor was scarcely colored yellow; but notwithstanding every attempt to obtain well-characterized crystals, it only gave a crystalline powder of a slightly yellowish-white, which was nearly deprived altogether of color, by washing in ether and pressure between folds of paper. To this substance we apply the name of *rhamnin*.

“The crystalline powder has great analogy with *quercitrin*, obtained when disturbed during crystallization. It has a bitter taste, is soluble in water, in alcohol and ether. Exposed to the air, the solution rapidly becomes yellow. Acids turn it yellow, alkalies immediately dark brown; barytes and lime-water produce the same effect.

“*Rhamnin*, under the influence of oxidizing agents, such as nitric and chromic acids, bichromate of potash, sulphuric acid and peroxide of manganese and free oxygen, becomes of a dark-yellow color, and is converted into a new principle, which we name *rhamnein*.

“*Rhamnein* may be obtained by exposing a solution of *rhamnin* to the atmosphere; it crystallizes with great difficulty, and forms a

FRIESLAND GREEN.

dark-yellow powder, which appears under the microscope to consist of minute crystals.

"This substance behaves like a true acid towards litmus and bases. With oxide of lead, lime and alumina, &c., it forms orange-yellow salts, *rhamneates*, in definite proportions.

"Rhamnein is not very permanent when in the free state. By contact with the air or pure oxygen, it absorbs this element in the course of time, and becomes of a red and brown color, to which the red and brown matters always present in decoction of Persian berries, owe their origin." (*Chem. Gaz.* ii. 430.)

FRIESLAND GREEN. Synonymous with Brunswick green. An ammoniated chloride of copper.

FUEL.

FRIT. See **GLASS.**

FROST. See **DEW.**

FRUGARDITE. See **IDOCRASE.**

FUCHSITE. See **MICA.**

FUCL. The essential components of the *Fucus amylaceus*, and similar species of the genus, are pectin, gum, starch, woody fibre, alkaline, earthy, iodine and bromine salts.

According to Schweitzer, the variable fertilizing power of different fuci is due to the difference in their alkaline ingredient. In the *F. vesiculosus* and *F. serratus*, the sulphates and other salts of potassa predominate, while in the *Laminaria saccharina*, soda and alkaline carbonates are in excess. The latter is also much richer in iodine. Below are the analyses of the ashes of several *Fuci*:

	Gödechens.				James.
	<i>F. digitat.</i>	<i>F. vesiculos.</i>	<i>F. nodosus.</i>	<i>F. serrat.</i>	<i>F. vesic.</i>
Potash	22.40	15.23	10.07	4.51	
Soda	8.29	11.16	15.80	21.15	15.10
Lime	11.86	9.78	12.80	16.36	16.77
Magnesia	7.44	7.16	10.93	11.66	15.19
Peroxide of iron	0.62	0.33	0.29	0.34	4.42
Chloride of sodium	28.39	25.10	20.16	18.76	9.89
Iodide of sodium	3.62	0.37	0.54	1.33	
Sulphuric acid	13.26	28.16	26.69	21.06	30.94
Phosphoric acid	2.56	1.36	1.52	4.40	
Silica	1.56	1.35	1.20	0.43	.69
Per-centage of ash	20.40	16.39	16.19	15.63	13.22

FUEL. *Ger.* Brennstoff, Brennmaterial. *Fr.* Combustible. Fuel embraces all combustibles employed for obtaining heat in furnaces, stoves, or fireplaces, and includes *wood, turf* and *coals*. Coals are of two kinds, *bituminous* and *anthracite*, from the former of which *coke* is made, which then resembles anthracite, but is porous. *Charcoal* is made from wood, and is lighter and more porous than coke. Fuel being often differently employed, according as it burns with or without flame, we distribute the above kinds into two classes, *wood* and *bituminous coal*, which burn with flame, and *charcoal, coke* and *anthracite*, which burn without flame.

Flaming fuel is required where the heat is to be carried some distance from the fire, as in reverberatory furnaces, where the material to be heated is separated from the fire by a partition or bridge, across which the flame plays. In a potter's kiln, the flame is made to circulate around and among piles of seggurs, and in a glass-house from one fireplace around a series of pots containing the glass. In simple draft (or wind) and blast furnaces, flameless fuel is almost always used, because the material to be acted on is placed in immediate contact with the fire. In domestic economy, either may be employed.

Omitting small quantities of foreign matter, flameless fuel consists of carbon alone, and flaming fuel of carbon and hydrogen. The resulting products of perfect combustion are carbonic acid from the carbon, and water from the hydrogen, both the carbon and hydrogen taking up oxygen from the air to form these compounds respectively. Where the com-

bustion is imperfect, as when there is an insufficient supply of air (oxygen), hydrogen still produces water; but carbon unites with only half as much oxygen, forming carbonic oxide. Now the heat evolved being due to the combination of oxygen with the two constituents of fuel, where a smaller amount combines with carbon, as in the formation of carbonic oxide, the heat developed will be less than when carbonic acid is generated. But if the carbonic oxide rising from the fire be burned by a supply of air, it forms carbonic acid, so that heat will again be developed; and the sum of the heat developed by the production of carbonic oxide and then of carbonic acid, will be equal to that produced by the perfect combustion of carbon and the immediate production of carbonic acid. Again, carbon and hydrogen, in flaming fuel, tend to form gaseous carburetted hydrogens, which will always be formed, where the supply of air is not duly regulated, and be carried beyond the sphere of combustion. When this takes place a quantity of carbon and of tarry matter, rich in carbon, will be carried up and pass off as black smoke, to the loss of just so much fuel, beside the inconvenience of volumes of black smoke. As perfect a combustion of fuel, therefore, as is consistent with economical arrangements, is desirable for attaining the greatest economy in the use of fuel.

Amount of heat. Despretz determined that the quantity of heat developed by the combustion of fuel, is in direct proportion to the quantity of oxygen consumed. (See **COMBUSTION.**) This quantity of heat cannot be abso-

FUEL.

lutely, but may be relatively measured, with some degree of accuracy, by determining from given weights of fuel either, 1, the quantity of ice melted, 2, the quantity of water heated from one given thermometric point to another, 3, the quantity of water evaporated, or 4, the time during which an apartment may be heated to the same point. The first method was employed by Lavoisier and others, and is less accurate than the other methods. The second is sufficiently practical, and was employed by Despretz in his valuable series of experiments. The third method, or the evaporative power of fuel, is thoroughly practical, and especially applicable to determine the value of fuel for steam boilers. The fourth, employed by Marcus Bull, has been successfully used in the best series of experiments ever instituted to determine directly the relative heating power of fuel.

M. Bull constructed one apartment within another, and while the outer chamber was maintained at a uniform temperature, the inner one was kept, by combustion of the fuel,

FUEL.

10° higher. The comparative lengths of time during which the inner apartment was maintained 10° higher than the outer, expressed the relative value of the kinds of fuel tried. Although his experiments demanded much time, cost and patience, it must be regretted that the early date at which they were made prevented his experimenting with the various kinds of coal, anthracite and bituminous, which have since become of high commercial importance; and that he did not sufficiently extend his valuable researches upon different kinds of coke and charcoal. He employed a small stove in the inner room, with some 40 ft. of pipe and many elbows, and by means of a damper could regulate the rapidity of combustion, so as to maintain the temperature at a given point until the fuel was consumed. One important conclusion to which he arrived was, that equal weights of different woods, made equally dry, produce equal quantities of heat (or as 60 : 64). The following tables comprise the results of his extensive and valuable experiments:—

Woods and Coals.	Specific Gravities of dry Wood.	Avoirdupois pounds of dry Wood in one cord.	Product of Charcoal from 100 parts of dry Wood, by weight.	Specific Gravities of dry Coal.	Pounds of dry Coal in one Bushel.	Pounds of Charcoal from one cord of dry Wood.	Bushels of Charcoal from one cord of dry Wood.	Time 10° of Heat were maintained by the combustion of one pound of each article.	Value of specified quantities of fuel, Shell-bark Hickory = 100.
White ash (<i>Fraxinus americana</i>)....	.772	3450	25.74	.547	28.78	888	31	H. M	Cord.
Apple tree (<i>Pyrus malus</i>)	.697	3115	25	.445	23.41	779	33	6 40	77
White beech (<i>Fagus sylvestris</i>)	.724	3236	19.62	.518	27.26	635	23	6	70
Black birch (<i>Betula lenta</i>)	.697	3115	19.40	.428	22.52	604	27	6	65
White birch (<i>Betula populifolia</i>)	.530	2369	19	.364	19.15	450	24	6	63
Butter-nut (<i>Juglans cathartica</i>)	.567	2534	20.79	.237	12.47	527	42	6	48
Red cedar (<i>Juniperus virginiana</i>)....	.565	2525	24.72	.238	12.52	624	50	6 40	51
American chesnut (<i>Castanea vesca</i>) ..	.522	2333	25.29	.379	19.94	590	30	6 40	56
Wild cherry (<i>Cerasus virginiana</i>) ...	.597	2668	21.70	.411	21.63	579	27	6 10	52
Dog-wood (<i>Cornus florida</i>)	.815	3643	21	.550	28.94	765	26	6 10	55
White elm (<i>Ulmus americana</i>)	.580	2592	24.85	.357	18.79	644	34	6 40	75
Sour gum (<i>Nyssa sylvatica</i>)	.703	3142	22.16	.400	21.05	696	33	6 20	58
Sweet gum (<i>Liquidambar styraciflua</i>)	.634	2834	19.69	.413	21.73	558	26	6	67
Shell-bark hickory (<i>Juglans squam.</i>)	1.000	4469	26.22	.625	32.89	1172	36	6 40	57
Pig-nut hickory (<i>Juglans porcina</i>) ..	.949	4241	25.22	.637	33.52	1070	32	6 40	100
Red-heart hickory (<i>Juglans lacin.?</i>) ..	.829	3705	22.90	.509	26.78	848	32	6 30	95
Witch-hazel (<i>Hamamelis virginica</i>)..	.784	3505	21.40	.368	19.36	750	39	6 10	81
American holly (<i>Ilex opaca</i>)	.602	2691	22.77	.374	19.68	613	31	6 20	72
American hornbeam (<i>Carpin. amer.</i>)	.720	3218	19	.455	23.94	611	25	6	57
Mountain laurel (<i>Kalmia latifolia</i>) ..	.663	2963	24.02	.457	24.05	712	30	6 40	65
Hard maple (<i>Acer saccharinum</i>)....	.644	2878	21.43	.431	22.68	617	27	6 10	66
Soft maple (<i>Acer rubrum</i>)	.597	2668	20.64	.370	19.47	551	28	6	60
Large magnolia (<i>Magnolia grandifl.</i>)	.605	2704	21.59	.406	21.36	584	27	6 10	54
Chestnut white-oak (<i>Qu. prin. palus.</i>)	.885	3955	22.76	.481	25.31	900	36	6 30	56
White oak (<i>Quercus alba</i>)	.855	3821	21.62	.401	21.10	826	39	6 20	86
Shell-bark white oak (<i>Querc. obtus.?</i>)	.775	3464	21.50	.437	22.99	745	32	6 20	81
Barren scrub-oak (<i>Quercus catesbaei</i>)	.747	3339	23.17	.392	20.63	774	38	6 30	74
Pin-oak (<i>Quercus palustris</i>)	.747	3339	22.22	.436	22.94	742	32	6 20	73
Scrub black oak (<i>Quercus banisteri</i>) ..	.728	3254	23.80	.387	20.36	774	38	6 30	71
Red oak (<i>Quercus rubra</i>)	.728	3254	22.43	.400	21.05	630	30	6 20	69
Barren oak (<i>Quercus ferruginea</i>)....	.694	3102	22.37	.447	23.52	694	29	6 20	66
Rock chestnut-oak (<i>Qu. prinus mont.</i>)	.678	3030	20.86	.436	22.94	632	28	6	61
Yellow oak (<i>Quercus prinus acum.</i>) ..	.653	2919	21.60	.295	15.52	631	41	6 10	60
Spanish oak (<i>Quercus falcata</i>)	.548	2449	22.95	.362	19.05	562	30	6 20	60
Persimmon (<i>Diospyros virginiana</i>)....	.711	3178	23.44	.469	24.68	745	30	6 30	52
Yellow pine, soft, (<i>Pinus mitis</i>)	.551	2463	23.75	.333	17.52	585	33	6 30	69
Jersey pine (<i>Pinus inops</i>)	.478	2137	24.88	.385	20.26	532	26	6 40	54

FUEL.

FUEL.

Woods and Coals.	Specific Gravities of dry Wood.	Avoirdupois pounds of dry Wood in one cord.	Product of Charcoal from 100 parts of dry Wood, by weight.	Specific Gravities of dry Coal.	Pounds of dry Coal in one Bushel.	Pounds of Charcoal from one cord of dry Wood.	Bushels of Charcoal from one cord of dry Wood.	Time 10' of Heat were maintained, by the heat of one pound of each article.	Value of specified quantities of each art., Shell-bark Hickory = 100.
Pitch pine (<i>Pinus rigida</i>).....	·426	1904	26·76	·298	15·68	510	33	H. M. 6 40	Cord. 43
White pine (<i>Pinus strobus</i>).....	·418	1868	24·35	·293	15·42	455	30	6 40	42
Yellow poplar (<i>Liriodendron tulipif.</i>)	·563	2516	21·81	·383	20·15	549	27	6 10	52
Lombardy poplar (<i>Populus dilatata</i>)	·397	1774	25	·245	12·89	444	34	6 40	40
Sassafras (<i>Laurus sassafras</i>).....	·618	2762	22·58	·427	22·47	624	28	6 20	59
Wild service (<i>Aronia arborea</i>)....	·887	3964	22·62	·594	31·26	897	29	6 20	84
Sycamore (<i>Acer pseudo-platanus</i>)....	·535	2391	23·60	·374	19·68	564	29	6 40	52
Black walnut (<i>Juglans nigra</i>).....	·681	3044	22·56	·418	22	687	31	6 20	65
Swamp whortle-berry (<i>Vacc. corym.</i>)	·752	3361	23·30	·505	26·57	783	29	6 30	73
Lehigh coal				1·494	78·61			13 10	99
Lakawaxen coal.....				1·400	73·67			13 10	99
Rhode Island coal				1·438	75·67			9 30	71
Schuylkill coal				1·453	76·46			13 40	103
Susquehanna coal				1·373	72·25			13 10	99
Swatara coal				1·459	76·77			11 20	85
Worcester coal				2·104	110·71			7 50	59
Cannel coal				1·240	65·25			10 30	230
Liverpool coal.....				1·331	70·04			9 10	215
Newcastle coal.....				1·204	63·35			9 20	198
Scotch coal				1·140	59·99			9 30	191
Karthauss coal				1·263	66·46			9 20	208
Richmond coal				1·246	65·56			9 20	205
Stony creek coal				1·396	73·46			9 50	243
Hickory charcoal.....				·625	32·89			15	166
Maple charcoal.....				·431	22·68			15	114
Oak charcoal.....				·401	21·10			15	106
Pine charcoal				·285	15			15	75
Coke.....				·557	29·31			12 50	126
Composition of two parts Lehigh coal, one charcoal, and one clay, by weight. }								13 20	

Evaporative power. Despretz found that 1 lb. of pure carbon evaporated 12·3 lbs. of water, from the temperature of 32°. Fyfe's experiments showed that 1 lb. coke evaporated 7·4 lb. water from 42°, which, calculated to 32°, amounts to 7·33 lbs. water. The amount of carbon in 1 lb. of the coke was 0·81 lb., which by Despretz's result, should have evaporated 9·96 lbs. water; there was a loss, therefore, of 2·63 lbs. or 26 pr. ct. of evaporative power. 1 lb. of the coal evaporated 5·66 lbs. water from 32°; and the same coal yielded 0·525 lb. coke, which should evaporate 3·84 lbs. water. Hence the practical evaporative power of coke is much less than that of the coal from which it is made. The per centage of fixed carbon in the coal is 50, and according to Despretz's result, it should evaporate 6·16 lbs. water, while we have seen that it evaporated 5·66, which is so near the theoretical quantity, that Fyfe concludes that the practical evaporative power is in proportion to the fixed carbon of coals.

From the numerous experiments of W. R. Johnson on coals, he concludes that their evaporative power is in proportion to the whole amount of carbon they contain, both fixed and volatile. As this is a question of

great practical importance, it should be determined by careful ultimate analysis of the coals, whose evaporative power is tested. See Johnson's *Report on Coals*.

The loss of evaporative power in the ordinary combustion of bituminous coals, is about 50 pr. ct. Assuming that the average content of Scotch coal is 50 pr. ct. fixed carbon, and that 1 lb. of such coal will yield 4·46 cubic ft. of gas, then the fixed carbon ought to evaporate 6·15 lbs. water; and calculating the oxygen requisite for the gas, the latter should evaporate 3·19 lbs., or both together 9·34 lbs. water. But by calculating the oxygen requisite for the whole coal, the latter should evaporate 11·3 lbs.; therefore the difference 11·3 — 9·34 = 1·96 (or 17 pr. ct.), represents the loss of evaporative power from the formation of tar, oils, &c. If Fyfe's conclusions be correct, the practical evaporative power of such coal is only 5·66 lbs., while calculated from the oxygen requisite for perfect combustion, it should be 11·3 lbs.; so that there is a loss of 50 pr. ct. of the fuel for evaporation.

Experiments were instituted to save this loss of fuel, by the introduction of steam and air above the fire, in order to consume the smoke. The steam was admitted through a

tube terminating in a fan-shaped distributor, and air at the same time through the door or small openings. The moment the steam and air entered, the dense volumes of black smoke disappeared. 1 lb. coal evaporated 10.76 lbs. water from 32° (an average of 10 experiments), while the same coal, without the use of steam and air, evaporated 6.17 lbs. from 32°. It was found by trial, that 4 pr. ct. steam of the quantity evaporated, was required to produce the effect. Now the 10.76 diminished by 4 pr. ct., gives 10.33 as the true evaporative power; and by subtracting from this 6.17, it leaves 4.16, or about 40 pr. ct. of fuel saved by the use of steam and air above the fire. Even by a direct estimate of the quantity saved by the use of steam and air, it amounted to 34 pr. ct. The economy depends on the manner in which the steam is employed. A certain quantity of air should be admitted with the steam, or otherwise the combustion is imperfect; even all the air required for combustion may be admitted above the fire, and the ash-pit closed. The air and steam should issue near the freshly-ignited coals, the well-ignited coals pushed back, and fresh coals thrown in near the distributor. The draft should not be too strong, for the introduction of steam increases it, and carries off heat before it acts evaporatingly. These results demand consideration and close investigation, in order to attain to a greater evaporative power from the use of bituminous coals. See *Fyfe, Edinb. Journ.* xxx. 256, 1841; *Richardson, Phil. Mag.* 1838.

Wood. Since equal weights of dry wood produce equal amounts of heat (*Bull*), it would be advisable to purchase it by weight; but as the quantity of water in wood brought to market is very variable, it is better to purchase by measurement or the cord, and determine the quality of the wood by observation. *Bull* found that the average absorption of moisture by 46 different kinds of perfectly dried wood kept in an apartment without fire for 12 months, was 10 pr. ct., the less dense woods absorbing the greater quantity. Green hickory lost 37½ pr. ct. moisture, by thorough drying, white oak 41 and soft maple 48 pr. ct. The average amount of moisture in green wood is 42 pr. ct.; in wood air-dried by a year's exposure under cover, it amounts to 25 pr. ct., all of which is in the hygrometric state, and not chemically combined.

According to Rumfort and Tredgold, 1 lb. dry wood will convert 2½ lbs. water into steam, from the ordinary temperature of 52°. But in 100 lbs. green wood there are 17 lbs. more water than in wood of ordinary dryness (42 — 25 = 17); and to convert this into steam requires 6.8 lbs. or pr. ct. of dry wood, nearly all of which is lost. Add to this the 17 lbs. excess of water, and we have a loss of at least 23 pr. ct., which is still farther increased by a more imperfect combustion. As moisture, however, only affects the weight and scarcely the bulk of wood, the loss in burning a measured quantity of green wood, as a cord, is due to the 6.8 pr. ct. of water evaporated, and to less perfect combustion, a loss which amounts probably to 10 pr. ct.

Coal. The greater or less amount of moisture in coal, is of inferior moment. But the quantity of ashes coals may contain deserves consideration. Coals may contain from 1 to 12 pr. ct. ashes (sometimes more); and comparing two coals having 1 and 11 pr. ct. ash respectively, the difference shows a loss of 10 pr. ct. fuel in burning the latter. A large quantity of ash, however, is practically so inconvenient, that such coal will not be used where other can be had. The nature of the ash is of some consequence. From some coals, especially the more free-burning, the ash exhibits a red color, due to oxide of iron; and hence such coals employed at a strong heat, produce a semi-vitrified mass (silicates of iron, alumina, magnesia, &c.) or cinder, which is often an inconvenience, from the frequent necessity of cleaning such a fireplace. The removal of cinder from grate-bars is difficult, unless it be done at a red heat. Among anthracites, the difference in the amount of volatile matter (from 12 to 1 pr. ct.) determines a free-burning coal or not, and may be selected according to the object in view. See **ANTHRACITE. COAL. FURNACE. HEATING.**

FULIGINOUS. The dark, smoky flame with which some substances burn, is considered one of their characteristics, and is termed fuliginous from *fuligo* (Lat.), soot.

FULLERS' EARTH. See **CLAY.**

FULMINIC ACID. See **CYANOGEN.**

FUMARIC ACID. Syn. Paramaleic. Formula of the hydrated acid, $C_4H_4O_6$, HO. Occurs in the *Fumaria officinalis*, in Iceland moss, and is formed artificially by heating *malic* acid to the melting point, and continuing it so for a length of time. It crystallizes in thin, rhombic prisms, is soluble in 200 pts. cold water, and in less of hot water and alcohol. Hagen procured *fumaramide* ($C_4H_4O_6 + NH_2$), by digesting *fumaric* ether with aqua ammoniæ. It is a very white powder, scarcely soluble in either cold water or alcohol.

FUMIGATION. From *fumigo*, to perfume. The diffusion of powerfully odorant volatile substances in infected apartments, so as to neutralize the effluvia of their offensive atmosphere.

FUNGI. A genus of inferiorly organized plants. Some are poisonous, others highly nutritive. The ashes of the incinerated fungi are rich in phosphates, and their large content of water in a measure explains their very rapid growth and tendency to decomposition.

Schlossberger and Döpping's analyses of fungi resulted as follows:—

	Water.	Sol. Sub.	Ashes.	Nitrogen.
<i>Agaricus deliciosus</i> ..	80.9	13.1	0.90	0.61
“ <i>arvensis</i>	90.6	9.4	1.08	0.77
“ <i>glutinosus</i> ..	93.7	6.3	0.30	0.29
“ <i>russula</i>	91.2	8.8	0.83	0.37
“ <i>cantharellus</i>	90.6	9.4	1.05	0.30
“ <i>muscarius</i> ..	90.5	9.4	0.84	0.59
<i>Boletus aureus</i>	94.2	5.6	0.38	0.26

According to these chemists, the alimentary power of fungi is due to **PROTEIN**, one of their solid ingredients. They found also traces of starch, mannite and fermentable sugar. Some of the poisonous fungi, they say, may *probably*

be rendered available as aliments, by proper cooking or slight additions. (*Chem. Gaz.*, 1845.)

Riegel, whose previous examinations of *fungi* are noted in the *Jahrb. für Prakt. Phar.*, vol. 7, found the composition of truffles to be fat oil, with traces of essential oil, an acid resin, osmazome, *fungic acid*, mushroom sugar, BOLETIC ACID, potassa, ammonia, vegetable gelatin and albumen, pectin and *fungin*.

Fungic Acid. A syrupy, colorless liquid, with an acid, acrid taste. Mixes with water and alcohol in all proportions, but dissolves in ether only in limited proportion. When dried it deliquesces readily, and cannot be obtained crystallized. With ammonia it forms a salt, which, with an excess of acid, crystallizes in large, regular prisms. The lime-salt is in small, 4-sided prisms. It precipitates lead and silver solutions only when in combination with bases, for both of these fungates are easily soluble in free acid.

Fungin. A whitish fibro-cellulose, slightly elastic substance, forming the basis of mushrooms and fungi generally. Distilled with nitric acid it yields prussic acid, artificial tannin, oxalic acid and a fatty substance. It was considered by Brœmos as a distinct and peculiar principle, but the examinations of Payen and Fromberg, corroborated by those recently of Schlossberger and Dœpping, show that when well cleansed, it is identical with cellulose. Hence, *fungin* no longer forms one of the vegetable proximate substances.

FURFURIN. A substance ($C_{36}H_{12}N_2O_6$) discovered by Fownes, and said to be isomeric with the amides. It is vegeto-alkaline, and forms saline compounds with the various acids.

Furfusol. A volatile oil ($C_{15}H_6O_6$), obtained by distillation from a mixture of bran, sulphuric acid and water. When free from water is colorless, but darkens on exposure. The presence of water lessens its tendency to change. Spec. grav. 1.168, and boiling point 323° Fahr.; is soluble, to a great extent, in cold water and alcohol. In contact with 5 or 6 times its bulk of ammonia, it becomes converted into a yellowish white, partially crystalline mass, which is easily soluble in water. This substance (*Furfuramide*, $C_{15}H_6NO_3$) is classed by Fownes, the discoverer, with the amides.

FURNACE. *Tech. Ger. Ofen. Fr. Fourneau*. The apparatus or structure in which fuel is consumed, for producing heat in the arts. They are of various forms and dimensions, but may be reduced to three kinds.

1. *Wind furnace. Fr. Fourneau à vent. Ger. Windofen, Tiegelofen*. The combustion is maintained by a simple draft of air, and the material to be operated on is usually enclosed in crucibles; rarely, as in a lime-kiln, mingled with the fuel. Steam boilers are of this kind. In glass and steel furnaces, in kilns for pottery and porcelain, the glass, steel or clay wares are contained in clay crucibles or seggurs, in which they are indurated or brought to fusion, without contact with, or injury from the fuel. The degree of heat in a wind-furnace is inferior to that produced by a blast, but is sufficient for most operations in the arts; moreover the heat may be increased by increasing

the height of the chimney. Its inconvenience lies in the smaller amount of material subjected to the fire, from the necessity of using crucibles.

Pl. III. figs. 3, 4, 5, 9, 10; Pl. IV. figs. 1, 2, 3, 6, 7, 8, are crucible furnaces. The muffle for gilding and painting porcelain and fine pottery, is also a wind-furnace.

2. *Reverberatory or Flame furnace. Ger. Flammofen. Fr. Fourneau à reverbère*. Is a horizontal lying furnace, heated by a draft of air (rarely by a blast), in which the material to be acted on is not in contact with the fuel, but placed upon a hearth on a level with the fire, from which it is separated by a bridge. Flaming fuel is almost always used, and its flame, made to rebound by the low arch over the fire, strikes across the bridge upon the long hearth, and reverberates or rolls in volumes towards the flues at the extreme point from the fire, heating the material spread over the whole hearth. It is employed for fusion, calcination, roasting, reduction, or compounding.

The heat of flame is very great, and hence this kind of furnace is capable of producing powerful effects. For calcination or roasting at moderate temperatures below a red heat, anthracite or other flameless fuel may be employed. One great advantage of a reverberatory lies in the cleanliness of its operations, the material being only heated by flame, and therefore scarcely contaminated by the ashes of fuel. A large amount of matter may be acted on by a comparatively small fire; and hence this furnace is peculiarly well adapted to calcination or roasting. The heat of the furnace and free entrance of air can be regulated by dampers and doors, so that it is well adapted to puddling iron, and to the successive operations of roasting and reduction, without removing the material. It farther presents the convenience of rabbling or working the material on the hearth, and of raking it out upon a clean pavement.

Pl. III. figs. 1, 2; Pl. IV. figs. 4, 5, are reverberatories for smelting and fusion. Pl. III. figs. 7, 8, represent a peculiar form of roasting reverberatory, arranged like a muffle. Pl. IV. figs. 9, 10, exhibit a simple roasting reverberatory, for arsenical ores. Pl. VI. figs. 9, 10, show an English reverberatory for roasting copper-ore; figs. 11, 12, for fusing the roasted ore into copper-stone. The cupel, for extracting silver from lead, is also a reverberatory of peculiar form. See SILVER.

3. *Blast furnace. Ger. Schachtofen. Fr. Fourneau à courant d'air forcé*. In these furnaces the material to be acted on is mingled with fuel and flux, and a blast of air forced through the mass. Since the heat developed by combustion depends on the quantity of oxygen consumed, the large quantity of air forced in by the blast determines a rapid combustion and a consequent production of intense heat, higher than is attained by any other kind of furnace. It is employed in the smelting or reduction of metals, and a hearth or crucible at the bottom is designed to receive the smelted metal and slag. The common blacksmith's forge is the simplest form of the blast furnace. Other kinds are the Scotch hearth, or very low

FUSIBLE METAL.

blast furnace (2 ft. high), for smelting galena; the slag-hearth (*Ger.* Krummofen, *Fr.* Fourneau courbe ou à manche), a low blast furnace about 5 ft. high, used for smelting lead-slag, galena, copper-ore, &c.; the medium blast furnace (*Ger.* Halbhofen, *Fr.* Demihaute fourneau), from 10 to 18 ft. high, for smelting copper-ores; and the blast furnace (*Ger.* Hofen, *Fr.* Haute fourneau), from 20 to 60 ft. high, mainly confined to smelting iron-ores. By mingling fuel and ore together, the latter is both the source of heat and the reducing agent; but this mixture proves sometimes an inconvenience, for ashes of the fuel or sulphur of the coals unite with the metallic body, and adulterate it.

Pl. III. figs. 1, 2, show a medium blast furnace, for smelting copper-stone. The Scotch hearth, see under LEAD, and the high blast furnace, see under IRON. For smaller chemical furnaces, see LABORATORY.

FUSIBLE METAL. So called from its ready fusibility, even in boiling water. Bismuth 5 pts., lead 3 pts., tin 2 pts.; or, Bi 8, Pb 5, Tin 3 pts. Some of these alloys melt at a little above 200°. See ALLOY.

FUSION. *Chem.* The passage of a solid into the liquid state, by heat. Solids differ materially in their fusibility, or in the degree of heat required to fuse or melt them. Thus, while mercury is liquid at all ordinary temperatures, and pure alcohol has never been obtained in the solid form, iron requires a strong white heat for fusion, and iridium is scarcely, if at all, fused by the hydroxygen blowpipe. But while different substances vary in their respective fusibilities, the same body is always fusible at the same temperature, under the same conditions of purity, relative quantity of matter to the heat, &c. An apparent exception to this rule exists among some organic, and probably inorganic bodies, which are capable of allotropic conditions; thus, a crystalline organic body, fusing at a certain point, is after fusion amorphous and fusible at a different point. *Wöhler.*

The following table comprises the fusing points of a few bodies:—

- 121° Solid compound of alcohol and carbonic acid.
- 47° Sulphuric ether.
- 45° Nitric acid.
- 39° Mercury.
- + 1° Oil of vitriol.
- + 14° Spirits of turpentine.
- + 25° Blood congeals.
- + 32° Ice.
- + 36° Olive oil.
- + 108° Phosphorus.
- + 201° Rose's fusible metal.
- + 211° Newton's fusible metal.
- + 218° Sulphur.
- + 442° Tin.
- + 500° Bismuth.
- + 612° Lead.
- + 773° Zinc.
- + 800° Antimony.
- + 1869° Brass.
- + 1996° Copper.
- + 2200° Gold.
- + 2786° Cast iron.

FUSION.

While a body is in the act of fusion, its temperature does not rise, because the heat which enters into it becomes latent, and is termed *latent heat*, or the heat of liquidity. If this fusion takes place without the direct application of heat, heat is absorbed from surrounding bodies, as in the solution of various salts. (See FREEZING MIXTURES.) If a pound of ice, at 32°, be mixed with a pound of water at 167°, the ice will be melted, and the resulting temperature will be 32°; so that 167 — 32 = 135° of heat have disappeared by the liquefaction of the ice. If water above 32° be exposed to a temperature below 32°, it will go on cooling to 32°, and there remain stationary until the whole is converted into ice, during which it must be still giving off heat. If the water were at 59°, and it required 12 minutes to cool it down to 32°, it will require one hour (or 5 times as long) to freeze it entirely; therefore (59 — 32 = 27) 27 × 5 = 135°. Again, if a pound of ice and a pound of water, each at 32°, be exposed to the same steady heat, when the pound of ice will have melted, the pound of water will indicate 167°. The following table shows the heat of liquidity in several bodies, compared with an equal weight of water:—

	Latent heat.	Equiv.
Lead	12.54°	104
Bismuth	23.25°	71
Tin	24.00°	59
Sulphur	27.14°	16
Zinc	48.30°	32
Water	135.00°	9

According to Despretz, this heat, like specific heat, is inversely as the combining weights, as the above table shows approximately, with the exception of sulphur.

The temperature of freezing, solidification or congelation, generally coincides with that of fusion; but water and solutions of salts may be cooled many degrees below their points of congelation, without solidifying. Thus, a solution of sulphate of soda saturated above the freezing point, in a flask, may be cooled many degrees below 32°; but on opening the flask, or by agitation, or dropping in a minute solid, the whole mass suddenly congeals, and the temperature rises considerably. The point of fusion is always constant, that of congelation more variable, and hence the former is referred to as the standard. By solutions of salts in water, the freezing point of the latter is considerably diminished, even when the liquid is agitated; and the diminution seems to be in proportion to the quantity dissolved, if we estimate it by the point of fusion. In the following table, column 1 is the quantity of the salt dissolved in 1000 pts. of water; 2, the maximum of cold below 32°, at which congelation takes place during stirring in a copper vessel, surrounded by a freezing mixture; 3, the temperature at the commencement of congelation, or the fusing point. With more than 24.7 pts. of carbonate of soda, the salt crystallizes instead of the water. *Despretz.*

FUSTET.

GAHNITE.

Dry carb. Potassa.			Dry carb. of Soda.	
1.	2.	3.	2.	3.
6.173	3.22°	0.36°	2.18°	0.43°
12.346	4.12°	0.67°	2.75°	0.83°
24.692	4.34°	1.37°	2.59°	1.71°
37.039	4.91°	2.09°	—	—
74.078	5.87°	2.27°	—	—
148.156	9.09°	3.25°	—	—
Chloride of Sodium.			Chloride of Calcium.	
6.173	0.75°	0.65°	2.48°	0.41°
12.346	2.16°	1.28°	—	0.95°
24.692	4.05°	2.54°	2.02°	1.85°
37.039	4.98°	3.81°	7.06°	2.90°
74.078	9.63°	7.81°	10.06°	6.41°
148.156	15.89°	16.56°	17.98°	16.04°

It is in consequence of the fact just noted, that sea-water requires a lower temperature for freezing than fresh water.

Most bodies contract in passing from the liquid into the solid state, so that the solid sinks in its own liquid. Water is the most striking exception to this law, for ice is notably lighter than water. (See WATER.) Bismuth and cast iron are also exceptions, and probably silver and copper. Some alloys must also be excepted. See ALLOYS.

FUSTET. See SUMAC.

FUSTIC, *Old and new*. Both used as dyestuffs. The former is from the *Morus tinctoria*, the latter from the Venetian sumac (*Rhus cotinus*). The latter contains, besides an astringent and other unimportant constituents, the coloring matters, yellow, red, and brown.

The coloring principle of fustic (fustin) is obtained by precipitating the tannin with gelatin, from its decoction, evaporating the liquid nearly to dryness, and treating the residue with ether. The ethereal extract being then evaporated and diluted with water, is precipitated by hydrated oxide of lead, and the yellow lake thus formed decomposed by sulphuretted hydrogen. The liquid thus procured, decanted from its sediment, deposits colorless crystals of fustin. *Preisser*.

Fustin is soluble in water, ether and alcohol. Its taste is slightly bitter, and its solutions when in contact with air become colored, at the edge of the vessels. Sulphuric acid, in dissolving it, imparts a bright yellow tint. Persulphate of iron transforms it into a dark olive-green. Potassa, soda, and ammonia give it an immediate red color, of much beauty. *Preisser*.

Fustin is strongly analogous to RHAMNIN, but differs in its great tendency to absorb oxygen, and become changed into *Fustein*, which is an orange-colored varnish, very soluble in water and potassa solutions. Its aqueous solution becomes purple. Sulphuric acid dissolves it with a deep-red tint. On cotton, mordanted with alum, it gives an orange color.

Morin, the coloring principle of the *Morus tinctoria*, is subdivided into *yellow* and *white morin*. They both dye alumed stuffs yellow, and both sublime in crystals. (*Preisser*.) The aqueous solution of the *yellow* becomes green with persulphate of iron, whilst that of the *white* turns chestnut red. Exposure to air imparts a reddish tint to each.

These two are doubtless modifications of one and the same principle, and so shall be designated together as *morin*. The mineral acids, in dissolving morin, impart a yellow color. Alkalies and contact with the air, induce a beautiful orange shade. It is soluble in water, and by absorption of oxygen or by boiling, the solution changes to yellow, and yellow morin or *morein* is formed. The chromate of potassa produces the same effect in a shorter time.

Morein is volatile, and crystallizes in yellow laminæ. It is very soluble in alcohol, ether, but much less so in hot, scarcely so in cold water.

Its color is not permanent, as its tint is darkened by the action of alkalies, acids, and exposure; and hence, perhaps, the origin of the two coloring matters in yellow wood.

G.

GABRO. *Geol.* A rock composed of Labradorite and Diallage.

GADOLINITE. *Min.* Cryst. Oblique rhombic, with indistinct cleavage; massive, impalpable. H. = 6.5 — 7, G. = 4.18 — 4.35. Black; vitreous, subresinous; subtranslucent, opaque; conchoidal and splintery fracture; streak greenish gray.

Chem. Rel. The glassy, vitreous variety, when highly heated, becomes incandescent, does not fuse, and becomes black on thin edges. The variety with splintery fracture gives off water in a closed tube, and swells into cauliflower ramifications. It dissolves readily in borax, showing iron; slightly in mic. salt. Gadolinite from Kärarfvet, gives off water, fuses without swelling; it is dissolved both by borax and mic. salt. The two former appear to be $\frac{1}{2}$ silicate of yttria, with $\frac{1}{2}$ silicates of protoxides of iron and cerium, and contains, besides silica, yttria, terbia, glucina, oxides of cerium, lanthanum, erbium and iron. G. from Kärarfvet, is mainly $\frac{1}{2}$ silicate of yttria, with oxides of calcium, glucinum, cerium, iron, manganese. Omitting these last, its formula is $3\text{YO}, \text{SiO}_3$, and probably the general formula for gadolinite is $3\text{RO}, \text{SiO}_3$. It is allied to Orthite, Tschewkinite, Allanite and Cerine.

Local. Finbo, Broddbo, Kärarfvet, Ytterby in Sweden; Hitterön, Norway; Disco, Greenland; Ceylon.

GADNIN. See CODFISH OIL.

GAHNITE. *Min.* Syn. Automolite. Cryst. Regular, the 8-hedron and 3×8 -hedron; sometimes compounded parallel to an 8-hedral face. Pl. IX. fig. 52. Cleavage 8-hedral, perfect. H. = 7.5 — 8, G. = 4.26. Dark-green or black; vitreous, subresinous, rather dull; subtranslucent, opaque; streak white.

Chem. Rel. Unchangeable by heat; scarcely soluble in borax and mic. salt; in fine powder gives zinc fumes with soda, at a reducing heat; not decomposed with acids, and with great difficulty by alkali; the best decomposer is bisulphate of potassa. Form. $(\text{ZnO}, \text{MgO}, \text{FeO}) \text{Al}_2\text{O}_3$, or $\text{RO}, \text{R}_2\text{O}_3$, corresponding with magnetic iron, chromic iron, franklinite, &c

GALAM BUTTER.

Local. The mines of Nafversberg and Eric Matts, near Fahlun, Sweden, associated with galena, blende, garnet, gadolinite, &c.; Had-dam, Connecticut, with chrysoberyl, beryl, garnet and columbite.

GALAM BUTTER. A reddish white fatty matter, existing in the fruit of the *Phulwana* tree (*Bassia butyrea*). In taste and odor it is similar to coco butter, and is probably analogous in composition. It melts at 72° , is insoluble in water and alcohol, and rancidifies on exposure to air.

GALANGA. The root of the *Alpinia Galanga*. By repeated treatment with ether, and spontaneous evaporation, yields a crystalline substance. It is soluble in ether, less so in alcohol, and scarcely in water.

The volatile oil has the formula $C_{10}H_9O$. (Vogel.) It is yellowish, lighter than water, soluble in ether and alcohol, and on exposure to air loses its odor, and thickens.

GALBANUM. A resinous gum yielded by the *Ferula Galbanifera* (?) and *Galbanum officinale*. It comes in tears and lumps, from Persia and the Levant: that from the first-named source being frequently mixed with *Sagapenum*.

Its composition is—

	Pelletier.	Meissner.
Resin.....	66.86	65.8
Gum	19.28	22.6
Bassorin	—	1.8
Volatile oil and water.....	6.34	5.4
Bitter matter, with malic acid. traces.		0.2
Wood, water, and loss.....	7.52	4.2

Volatile Oil. Obtained limpid and colorless, by distilling the gum with water. Spec. grav. 0.912. Soluble in alcohol, ether, and the fixed oils.

Resin. Yellowish brown, transparent and tasteless. Ether and alcohol dissolve it, but oil of terpentine scarcely effects it, even by heat. According to Johnson, its formula is $C_{40}H_{27}O_9$; and Pelletier says that when heated up to 248° or 266° , it yields an indigo-blue oil.

GALENA. *Min.* Syn. Hexahedral Lead-glance, *M.* Sulphuret of lead, Blue lead, Blue mineral. *Ger.* Bleiglauz, Blau-Bleierz, Bleischweif.

Descrip. Cryst. Regular; generally the cube, sometimes combined with the 8-hedron and 12-hedron: the 8-hedron is rarely alone. All the holohedral forms have been observed, Pl. VIII. figs. 1—11, except the 6×8 -hedron, figs. 7 and 7, *a*. It is sometimes compounded like Pl. IX. fig. 52. Cleavage cubical. It also occurs in imitative forms, massive, granular and fibrous. $H. = 2.5 - 2.75$, $G. = 7.532 - 7.652$. Color and streak lead-gray; metallic, usually splendid; readily frangible; its easy cleavage almost conceals its fracture.

Chem. Rel. It fuses readily, giving off sulphur at a low heat, leaving a globule of lead; by a higher heat it gives off lead-smoke; in a tube it gives off sulphur and white sulphate of lead, which may be fused. An odor of arsenic or selenium, or white fumes of antimony may be sometimes obtained. The button of metallic lead may be cupelled for silver, and the stain left on the cupel may indicate the associated metals. See **CUPELLATION**.

GALLIC ACID.

It is essentially sulphuret of lead, PbS ; but it frequently contains antimony, sometimes recognised by its feathery surface, or silver, which cannot easily be recognised, unless present in quantity. The latter is termed *Argentiferous Galena*. A. A. Hayes found a galena from the Lubec lead mines of Maine, to be a mixture or compound of sulphurets of lead and bismuth. See **Metallurgic treatment of ores of LEAD**.

Local. It occurs extensively disseminated in primary and secondary rocks, most abundantly in limestone. There are numerous localities in Europe where it is worked both for lead and silver. The mines in Spain are probably most productive. Those of Derbyshire, &c., England, yield very large quantities. It is also worked on the Hartz, near Freiberg, &c., Germany; at Przibram, Bohemia; in Carinthia, &c. &c. In the U. S., the most remarkable lead region (and probably the greatest in the world), where the ore is disseminated in beds of greater or less extent, is in Wisconsin, Iowa, Illinois, Missouri, and Kentucky. The three former may be regarded as a distinct region of 90 miles from E. to W., and 60 miles from N. to S. Another district is in Missouri, to the S. of the Missouri river, about 80 miles N. and S. and 50 miles E. and W. The lower part of Illinois and part of Kentucky appears to be a third district. The 1st district is remarkable for the purity of its lead, and for enormous crystals of galena; there is also found calamine in quantity, and pyritous copper. The 2d gives often a less pure lead, is largely associated with very pure barytes; and one tract, Mine à la Motte, is the most interesting metallic region in the U. S.: a very large amount of native white lead is found there, massive, sometimes crystallized; the ore is associated with pyritous copper, cobalt, nickel, manganese and iron, together with their oxides, in sufficient quantities for exploration; a few miles distant is the well-known iron mountain. In the 3d district, much of the galena contains sulphuret of antimony. Although extensively explored, this immense metallic region of the Mississippi valley remains to be fully developed. The best argentiferous vein yet opened in the U. S., is probably that in Davidson Co., N. Carolina. See further, under **LEAD**.

GALL. See **BILE** and **GLASS**.

GALLIC ACID. Exists in galls and other vegetable matters containing **TANNIN**, by the oxidation of which substances it is generated.

Prep. It can be obtained by mere exposure to the air, of a solution of nut-galls, at a temperature of 75° to 85° . After several months, the mass being expressed, the residue upon treatment with boiling water yields crystals of gallic acid. The change this produced is, that 1 eq. tannin, $C_{18}H_8O_{12}$, by absorption of oxygen, is resolved into hydrated gallic acid, carbonic acid and water. Kent proposes to extract gallic acid from ink by ether, wherein it exists free and uncombined. His process has been repeated with success. *Am. Jour. Sci.*, Jan. 1844.

Prop. The pure hydrated acid crystallizes in colorless confused prisms or delicate

needles, which are soluble in 100 pts. of cold, and 3 pts. boiling water. Alcohol dissolves it readily, either less easily. It behaves to the salts of iron like tannin, but gives no precipitate with gelatin. The two in solution can be separated by the presence of a piece of old, untanned hide, which abstracts the tannin and leaves the gallic acid unacted upon. At 212° it loses 9.25 pr. ct. of water.

Free from air, solutions of gallic acid remain unchanged; but the access of oxygen eliminates carbonic acid, and causes the formation of a strongly colored product, supposed to be the *japonic acid*. The same result is produced by the action of the mineral acids or the alkalies. Solution of gallic acid is decomposed by chlorine. The perchloride of gold and nitrate of silver are reduced to a metallic state by its action. To the salts of peroxide of iron it imparts a deep-blue tint, in the cold, but by heating the mixture decolorization follows, carbonic acid is disengaged, and the peroxide salt reduced to protoxide. By precipitation from its cold solution in hot sulphuric acid, crystallized gallic acid ($C_7H_5O_3 + 3HO$) loses 1 eq. of water of crystallization, and 1 of basic water, and becomes $C_7H_5O_3$. In this state it is a reddish brown crystalline powder, insoluble in water but soluble in the alkalies, from which solutions, on exposure, it deposits in very soluble colored crystals. Its beautiful color and property of shading mordanted cotton like madder, renders it a probable substitute for that substance.

Subjected to distillation at 450° to 460° , hydrated gallic acid is transformed into pyrogallac acid, which passes over into the receiver and metagallic, which remains as the residue. The formation of the pyrogallac may be thus represented: 2 eq. monohydrated gallic acid lose 2 eq. carbonic acid and 2 eq. water. $C_{14}H_8O_{12} - (2CO_2 + 2HO) = C_{12}H_6O_6$. Gallic acid is bibasic, and forms with the alkalies salts which are soluble, and with the earths and metallic oxides those that are insoluble in water.

Of the *gallates* little is known, except their remarkable tendency to absorb oxygen when in contact with an excess of alkali, and they become decomposed. The *acid gallate of ammonia* is $C_7H_5O_3, NH_4O + C_7H_5O_3, 2HO$. The lead salt has the same composition and the bibasic gallate of that metal, $C_7H_5O_3, 2PbO$.

Pyrogallac Acid. Form. $C_{12}H_6O_6$. (*Baudrimont*.) It does not form an hydrate. (*Stenhouse*.) Is volatile at 410° , and when sublimed forms shining scales which are bitter and fuse at 240° . It gives a deep-blue color, but no precipitate with solutions of protosulphate of iron; but if there is any persalt present, the shade soon changes to a dark green, otherwise it will retain its blue tint for a length of time. Dropped into milk of lime, a reddish purple color ensues, speedily changing into a black-brown, and by these reactions it is best detected, as they discover its presence even in minute quantity.

Water dissolves it, alcohol less readily; and its solution in the latter resembles laudanum in taste. It reduces the oxides of gold, silver and platinum to the metallic state, and pre-

cipitates them completely from their solutions. (*Stenhouse*.) With the alkaline bases it forms soluble salts. The greater part of the pyrogallates of other bases are insoluble. That of lead contains $PbO, C_{12}H_6O_6$.

Metagallic Acid. Syn. Melangallic acid. Formed from the pyrogallac acid, by the loss of 3 eq. water. As found in the retort it is a lustrous, coal-black resin; but when dissolved in the alkalies and precipitated by an acid, it is a black powder, insoluble in water, alcohol and ether. Its combinations with the alkalies are of a deep black color, and according to Pelouze the composition of the metagallate of silver is $AgO, C_{12}H_3O_3$.

Ellagic acid, which see under GALLS, is a product of the slow fermentation of gallic and formic acids. The *Paraellagic* results when gallic acid is heated to 280° , with oil of vitriol. It drops from the cooling solution in bright scarlet crystals. This body forms red salts with bases, and is isomeric with ellagic acid; but this latter acid yields no paraellagic acid, when acted on by sulphuric acid.

GALLS. Carbuncular excrescences obtained from the *Quercus infectoria*, and due to an irritation or disease caused by the perforations of an insect into the bark of the tree. The black or blue, white and green galls designate the different varieties. The first named are most generally found in commerce.

Guibourt's analysis of gall-nuts gave Water 11.5, Woody fibre 10.5, TANNIN 65, GALLIC ACID 2, Ellagic and luteo-gallic acids 2, Brown extractive 2.5, Gum 2.5, Starch 2, Chlorophyll and volatile oil 0.7, Sugar 1.3, Albumen and salts.

Solution of Nutgalls. This is a valuable reagent for detecting the alkaloids and certain metallic salts, with the first of which it produces white, and with most of the latter colored precipitates. Its property of precipitating gelatin is lost after exposure to air. The characteristic behavior of a fresh decoction of galls, see under TANNIN.

Ellagic Acid. Exists also in the *Tormentilla vulgaris*. Is formed and found mixed with gallic acid, by long exposure of a solution of galls to the atmosphere, at 68° . Being insoluble in water it is left behind, when the gallic acid is acted upon by that agent. It is insoluble also in alcohol and ether, but is taken up by the alkalies, and reprecipitated again by the acids. By sublimation it forms minute needleform crystals. Pelouze's formula is $C_7H_2O_4$, which makes it isomeric with monohydrated gallic acid; but the later and more accurate researches of Wöhler and Taylor show it to be $HO + C_{14}H_2O_7$, and identical with BEZOARIC ACID.

Luteo-gallic Acid. The yellow coloring principle of the gallnuts may be separated from the ellagic acid by dissolving the two in potassa, and exposing the solution to the atmosphere. Proportional to the absorption of carbonic acid from the air, the ellaginate of potassa precipitates, while the luteo-gallate of potassa remains in solution.

Wöhler (*Ann. der Phar.*, 1845) supposes the formation of Bezoaric acid to take place from

an exposed solution of alkaline gallate with excess of alkali, and attributes its not being observed to the speedy change which the action of the air produces. It should be remarked, however, that a concentrated solution of bezoaric in potassa, when left open, presents the same blood-red color as a solution of gallic acid in potassa. Merklein and Wöhler both attribute the formation of bezoars to the transmutation of the tannic acid of the vegetable food of those animals in which they are found into bezoaric acid, the digestive process ceasing its action after this conversion.

Nutgalls are extensively used in **DYEING**, especially as a preparatory step to enable fibre to take up a larger amount of mordant. They are also employed in black dyes, and largely in the manufacture of **INK**.

GALL-STONES. See **BILIARY CONCRETIONS**.

GALLITZINITE. See **RUTILE**.

GALVANISM. See **ELECTRICITY**.

GAMBOGE. *Fr.* Gomme-gutte. The yellow resinous gum obtained from the *Gambogia gutta*, *G. Manaslogana*, and *Stalagmites Gambogies*. Buchner's analyses of two kinds gave

	<i>Singapore.</i>	<i>Ceylon.</i>
Fat acid.....	79.794	78.841
Coloring matter	0.573	4.030
Gum	19.519	12.595
Sediment (impurities). ..	0.114	4.534

Absolute ether dissolves out the fat, *Gambolic acid*, which is an inodorous, tasteless, transparent, red resin, extremely soluble in water, but difficultly so in alcohol, and not at all in water. With the alkaline earths and metals it forms insoluble combinations. With protoxide of tin it gives a bright yellow, with protoxide of iron, a brown, and with oxide of copper, a green color. It dissolves in potassa and sulphuric acid. Water precipitates it from its partial solution in nitric acid, in a modified form. Buchner's formula is $C_{60}H_{35}O_{12}$, and that of Johnston, $C_{40}H_{23}O_8$.

The lead compound = $5PbO + 2Gamb. acid$.
 " silver " = $AgO + Gamb. ac.$
 " baryta " = $3BaO + 4Gamb. ac.$

The residual matter, after the extraction of the fat acid, resin, and ether, when boiled with absolute alcohol, gives a reddish brown viscid extract, soluble in water; this property distinguishes it from the acid resin, and its solubility in alcohol from the gum. The gummy residue remaining after the action of the alcohol consists of $C_8H_5O_2$, and hence has the elementary composition of starch, or anhydrous sugar. (*Buchner*.)

Gamboge is employed in medicine, and as a water pigment of a golden color.

GANGUE. Veinstone. *Ger.* Gangart. The less valuable or worthless mineral body in which a valuable mineral is enclosed, or with which it is associated. The usual gangues are quartz, limestone, feldspar, fluor spar, barytes and gypsum, slate and sandstone. Valuable mineral substances are rarely found alone, excepting iron ores, coal, limestone, and salt; and they are taken up from their veins or beds with as little of the gangue as practicable. They are then separated from the gangue by

hand-picking, and the metallic ores generally by stamping and washing, by which most of the gangue is removed.

GANOMATITE. See **CHENOCOPROLITE**.

GARANCIN. See **MADDER**.

GARLIC. The bulb or cloves of the *Allium sativum*. Its constituents are, *acid volatile oil*, *extractive*, *gum*, *fibre*, *albumen*, *water*, *sulphur*, *starch*, *saccharine matter*, and *fixed salts*.

Oil of Garlic. Prepared by distilling the bruised cloves with water, and rectifying the product which passes over by redistillation with water. The pure oil is pale-yellow, and consists of C_6H_5S . It decomposes near 300° , at which point it boils. In rectifying, the salt-bath should be used, and the temperature kept within 284° . Alcohol and ether dissolve it readily, but in water it is scarcely soluble. Dilute acids produce no change. With potassium it forms a sulphuret; and according to Wertheim, the oil is a sulphuret of a new organic radical, which he calls *Allyl* = C_3H_5 .

The intimate analogy between this oil and that of mustard, has led to investigations which show that they are different compounds of one and the same radical, the latter being a sulphocyanic compound with allyl. These facts are further verified by the conversion of oil of mustard into that of garlic, merely by the abstraction of a part of its cyanogen and sulphur by the action of potassium. For an elaborate paper upon the subject, see *Ann. der Pharm. und Chem.* for 1845. There is also an oxide whose formula is probably C_5H_5O . It combines with nitrate of silver. The sulphuret forms a double compound with the chlorides of platinum, mercury, gold, and palladium, and with the sulphuret of palladium.

GARNET. *Min.* Syn. Dodecahedral Garnet, *M.* Melanite, Grossularite, Topazolite, Almandine, Aplome, Essonite or Cinnamonstone, Greenlandite, Pyrenaite, Colophonite, Allochroite, Romanzovite, Polyadelphite, Uwarowite. *Ger.* Granat, Braunsteinkeisel, Kaneelstein. *Fr.* Grenat.

Cryst. Regular. *Pl.* VIII. Fig. 2 is the most common form; Fig. 4 is frequent; and the combinations of Figs. 2 and 4, as in Fig. 5. Other forms are the 4×6 -hedron, Fig. 10, and the 6×8 -hedron, Fig. 7, but generally in combination with the preceding, as in Fig. 7a, which comprises the 12, 24 and 48-hedra. Cleavage imperfectly dodecahedral. It occurs also in curved lamellar masses, granular. *H.* = 6.5—7.5. *G.* = 3.5—4.3. Brown, red, yellow, green, white, black; streak white, yellowish white; lustre vitreous, resinous; subtranslucent, transparent; fracture subconchoidal, uneven. No mineral species presents a greater variety of external characters than garnet, in consequence of the replacement of isomorphous bases. The prevailing color is brownish red. Precious garnet is of a rich wine-red color, and often transparent; Cinnamonstone has a yellowish color and high lustre; Manganesian garnet has a dark brownish-red color; Polyadelphite is brownish yellow; Topazolite forms small yellow crystals; Grossularite occurs in green 24-hedra, *Pl.* VIII. Fig. 4, and Uwarowite in green 12-hedra; Melanite is velvety black, passing at times into dark green.

Pyrenaite is black or grayish black; **Allochroite** is dark, fine-grained, massive; **Aplome** is striated parallel to the shorter diagonal of the 12-hedral face; **Colophonite** is coarse granular, rarely well-crystallized, has a resinous lustre and an iridescent surface. **Pyrope**, see the close of this article.

Chem. Rel. The different varieties fuse with facility and quietly to a glass, which is black or gray, if rich in iron, or brownish or yellowish, if containing little iron; they dissolve readily in borax, giving the reaction of iron or manganese. They are generally decomposed with difficulty by muriatic acid, unless previously ignited, and some varieties even then imperfectly. They are all $\frac{1}{2}$ silicates of protoxides, RO, and of sesquioxides, R_2O_3 , and therefore their general formula is $3RO, SiO_3 + R_2O_3, SiO_3$. The bases RO are lime, magnesia, protoxides of iron, and manganese; the bases R_2O_3 are alumina, sesquioxides of iron, manganese, and chrome.

Although each variety contains more than two bases, yet they may be conveniently subdivided into six groups, of which the first four contain chiefly silicate of alumina, the fifth that of sesquioxide of iron, and the sixth sesquioxide of chrome.

1. **Lime Garnet.** Form. $3CaO, SiO_3 + Al_2O_3, SiO_3$. Includes white garnet, grossularite, cinnamon-stone, brownish and reddish yellow garnet, and romanzovite.

2. **Magnesia Garnet.** Form. $3MgO, SiO_3 + Al_2O_3, SiO_3$. A black garnet from Arendal.

3. **Iron Garnet.** Form. $3FeO, SiO_3 + Al_2O_3, SiO_3$. Includes precious garnet, brown, reddish brown, and almandine.

4. **Manganese Garnet.** Form. $3MnO, SiO_3 + Al_2O_3, SiO_3$.

5. **Lime and Iron Garnet.** Form. $3CaO, SiO_3 + Fe_2O_3, SiO_3$. Includes green, brown, blackish brown, and melanite. *Ram.*

6. **Chrome Garnet.** Form. $3CaO, SiO_3 + Cr_2O_3, SiO_3$. It is the uwarowite from Bissersk, Russia.

Pyrope. It is blood-red, translucent, uncrystallized, fusible with difficulty to a black glass, imparting a chrome-green color to mic-salt. It usually contains chrome, but it is uncertain whether as oxide or acid; and some specimens have been found without chrome. It is probable that **Pyrope** is a distinct species, since the formulas calculated from its analysis do not agree with the above.

Local. The localities of Garnet are very numerous, in nearly all primary rocks.

GAS. **Chem.** Van Helmont observed that during fermentation an air was evolved, different from atmospheric air, which he called *gas*, from the Dutch, *gäsch*, signifying foam. The name has since been applied to all highly elastic fluids. All ponderable bodies are either solid, liquid, or gaseous. Gases are elastic fluids, whose particles move freely among each other, and are destitute of cohesion; they may be expanded by heat or mechanical force, and compressed into a smaller bulk by cold and mechanical force; they are all transparent, and mostly colorless; chlorine, bromine, &c. are colored; they are capable of being weighed, and have very different specific gravities.

Origin. A few gases exist in nature, as oxygen, nitrogen, carbonic acid, vapor of water, &c., in atmospheric air. They are generally obtained by the action of heat on solids or liquids; thus black oxide of manganese and saltpeter will give off oxygen; camphor, water, and alcohol will rise in vapor, by heat. In the former case, the action of heat must be greater than the chemical attraction of oxygen for the remaining body; in the latter, the heat must overcome cohesive attraction. Gases are also obtained by employing a superior affinity; thus carbonic acid is expelled from carbonate of lime by sulphuric or muriatic acid. Sometimes, however, the capability of an elastic fluid being formed by the mutual action of two or more bodies, apparently causes the escape of gas, even in opposition to chemical affinity. In a few cases, a gas is formed by the removal of pressure at ordinary temperatures.

Division. Gases are divided conveniently into permanent or fixed, coercible, and vaporous gases. The first have never been condensed into liquids or solids by the combined agency of -300° cold and several hundred atmospheres of pressure; oxygen, hydrogen, nitrogen. Coercible gases are condensable into liquids at various temperatures and pressures, from 50° with 4 or 5 atmospheres, to 50° with 50 to 60 atmospheres; sulphurous, carbonic acids, &c. Vaporous gases are formed above common atmospheric temperatures, from bodies whose boiling points are above 77° . The last are commonly called vapors, but, strictly speaking, the term vapors should apply to them when they are cooled by the air so as to condense in visible particles; for in the true gaseous state they are invisible, if colorless, and become visible by condensation, as steam. For the condensation of vapors, see **EVAPORATION**, **DISTILLATION**, **VAPOR**. Faraday showed the condensation of many gases by introducing the solid material, from which the gas is to be produced (as carbonate of ammonia), into the longer leg of a glass tube, bent at an oblique angle, and the liquid (as sulphuric acid) into the shorter leg. The tube was then sealed, and the liquid let down upon the solid. The shorter leg was sometimes cooled artificially, or the longer leg warmed, or both operations were performed simultaneously; when the condensed gas (as carbonic acid) appeared as a liquid in the shorter leg.

Relations to light. All gases are transparent, most of them colorless; iodine is violet; sulphur, bromine, and peroxide of nitrogen, are reddish; chlorine is yellowish. By sudden compression they emit light. The following table by Dulong exhibits the refractive power of some gases, air = 1000.

Hydrogen	470
Oxygen	924
Air	1000
Nitrogen	1020
Nitric oxide	1030
Carbonic oxide	1157
Ammonia	1309
Marsh gas	1504
Carbonic acid	1526
Muriatic acid	1527

Prussic acid.....	1531
Nitrous oxide.....	1710
Sulphohydric acid.....	2187
Alcohol.....	2220
Sulphurous acid.....	2260
Olefiant gas.....	2302
Chlorine.....	2623
Cyanogen.....	2832
Muriatic ether.....	3720
Phosgen gas.....	3936
Sulphuret of carbon.....	5179
Ether.....	5280

Relations to heat. Gases contain a large amount of heat, which becomes free and sensible by compression or by condensation of vaporous gas. The quantity of heat, or the repellant, is just sufficient to counterbalance affinity, or the attractant. As we believe compounds are held together by different degrees of attraction, the amounts of heat ought therefore to be different. The same weight of saturated vapor always contains the same amount of heat, but the more of this is latent in proportion to low temperature and low pressure, and the more is sensible at higher temperatures and greater pressure. Thus in steam, the total amount of heat at 212° is from 988° to 1022° . Assuming it at 1000° , and adding the 180° between 212° and the freezing point, the total amount at 32° is 1180° .

Vapor at	Free heat.	Combined heat.	
32°	32°	1180°	} Total, 1212°
22°	122°	1090°	
212°	212°	1000°	
392°	392°	820°	

The latent heat of the following bodies are the quantities they contain above 32° : Alcohol = 771° , Ether = 410° , Spts. terpentine 623° .

Permanent gases are uniformly expanded by heat. See *EXPANSION* for a formula for reducing the volume of a gas at one temperature to that at another temperature. The coercible gases vary from Mariotte's law, and expand unequally the nearer they approach points of liquefaction. Thus, while the increase of volume by expansion of the permanent gases is for every 180° , 0.3665, it is 0.369 between 32° and 212° for carbonic acid, whose condensing point is -150° , and 0.3856 for sulphurous acid, which liquefies at about 0° to $+4^{\circ}$. Contraction by cooling is the reverse of expansion by heat.

Gases have different specific heats. It appears that the permanent, elementary gases have equal specific heats under equal volume and pressure. The following table by De la Roche and Bérard shows the spec. heats of some gases compared with an equal weight of water = 1000.

Carbonic acid.....	221.0
Oxygen.....	236.1
Nitrous oxide.....	236.9
Air.....	266.9
Nitrogen.....	275.4
Carbonic oxide.....	288.4
Olefiant gas.....	420.7
Steam.....	847.0
Hydrogen.....	3293.6

See HEAT.

For the condensation of gases in solids and liquids, see *ABSORPTION*. For the diffusive power of gases, see *DIFFUSION*, and for their contained moisture, see *HYGROMETER*. For the analysis of mixed gases, see *ANALYSIS*, and for testing separate gases, see their behavior under *OXYGEN*, *NITROGEN*, carbonic acid under *CARBON*, &c.

To collect gases for research or lecture-illustration, regard must be had to their properties. Thus ammonia, muriatic acid, &c. cannot be collected over water, because they are absorbed by it in some quantity. In such cases a mercurial bath will be found most convenient; but mercury cannot be employed if the gas combine with that metal in the cold. Chlorine and carbonic acid, by reason of their specific gravity, may be collected in dry vessels, by passing a tube from the gas-generator to the bottom of the vessel. But if chlorine is to be soon employed, it may be obtained over water, without a serious loss by absorption. For collecting and keeping larger quantities of gas, a copper gasometer or caoutchouc bag may be conveniently used. Much more care is requisite, if the gas be designed for research, to see that it is pure; and in order to this end, the properties of the gas must be accurately studied, in order to form a plan for its purification; nor can any general rules on this head be given. If the gas be required dry, this object is effected by passing it, after purification, through a tube containing fragments of fused chloride of calcium, or fragments of pumice or porous earthenware, imbued with oil of vitriol, or through strong oil of vitriol in a flask, or over fragments of caustic potassa. In the last case, both water and acids may be removed from the gas.

GAS, ILLUMINATING. *Tech.* The light produced by the combustion of the vapor issuing from bituminous coal heated in a retort, was observed, about 1680, by Mr. Clayton, of Yorkshire, England. It was observed and experimented on, a century after, by Drs. Hales and Watson. Lebon is said to have proposed illuminating gas from the destructive distillation of wood, in 1785, and in 1801 proposed a method of obtaining it from oily bodies. W. Murdoch first applied coal-gas for illumination in 1792, and made the first public display of it in 1802. Several works were erected in the few following years, and in 1823 there were four large gas companies in London, the first of which, begun in 1805, distributed gas through 122 miles of pipe. At present, the annual consumption in London is 3000 million cubic feet, = 50,000 to 60,000 tons of gas (100 cub. ft. = 4 lb., or 1 cub. ft. = 280 grs.). Since that period, most of the cities and towns in England, and many cities on the continent, have been lighted with gas. Its consumption is rapidly extending in the United States.

Manufacture. The preparation of illuminating gas is the process of *DESTRUCTIVE DISTILLATION* on a large scale, chiefly applied to bituminous coal. Fats and rosin are employed to some extent. The products of the distillation of coal are represented in the following scheme. (See also *COAL*.)

GAS, ILLUMINATING.

PRODUCTS OF THE DRY DISTILLATION OF COAL.

Residue = Coke, consisting of carbon and earthy matter.	
Volatile matter	Liquids
	Tar Yields by redistillation
	Coal naphtha
	Ammoniacal liquor
	Acid purifier
	Vitriol purifier
Gases	Lime purifier
	Gasometer

Residue = Pitch.

Naphthalin, paranaphthalin, benzin, leukolin, kyanolin (anilin), pyrrole, carbolic acid (phenylhydrate), rosolic and brunolic acids, &c.

Water, ammonia, carbonic, acetic, sulphurous, muriatic, sulphydric, cyanhydric, rhodanhydric, &c. acids.

Ammonia and some acids.

Ammonia.

Sulphydric, cyanhydric acids, &c.

Carbonic, sulphurous, sulphydric, and other acids.

Heavy and light carburetted hydrogens.

Vapors of naphtha, sulphuret of carbon, &c.

Carbonic oxide, hydrogen, nitrogen.

Fig. 74.

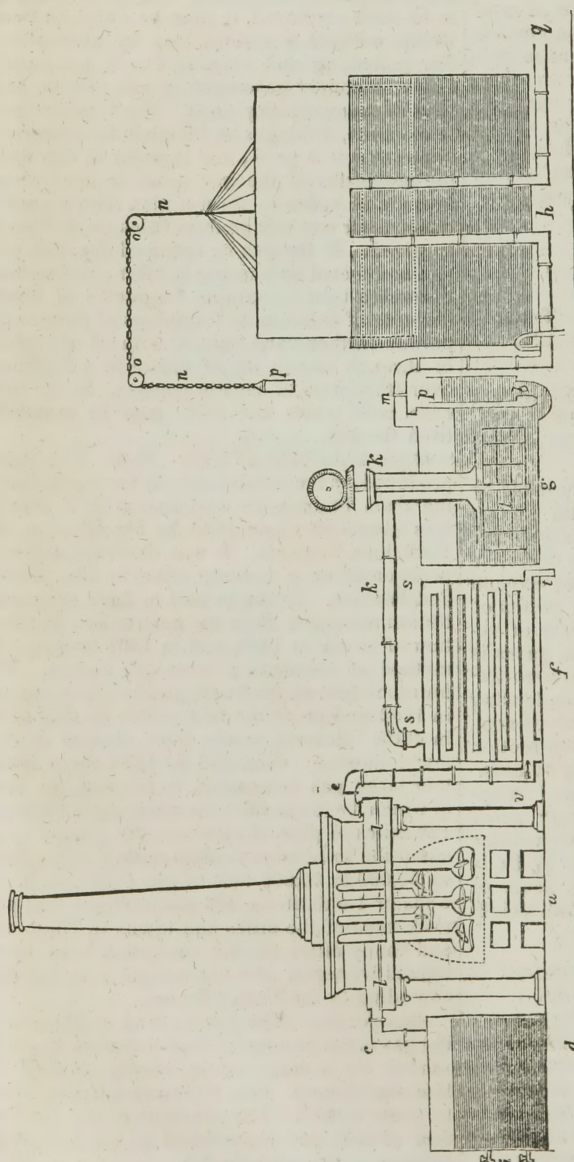
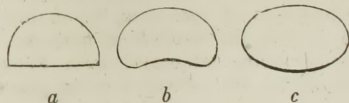


Fig. 74 illustrates the general arrangement of gas-works, although many modifications of the various parts have been proposed, and some of them adopted at particular works. The principal parts are the retorts, hydraulic main, washers, coolers and condensers, purifiers and gasometers. *a* is the furnace or stack of five retorts, from the front end of each of which a tube rises vertically, and then, curving downwards, enters the hydraulic main *b*. This is a horizontal iron tube, of a foot or more diameter, in which a large proportion of the liquid products condense, and filling it one-half, flow off from one end through the tube *c* into the tight tar-cistern, *d*. The heavier tar or the lighter ammoniacal liquor may be drawn off from the cistern separately by the cocks *i*. The ends of the tubes opening below the level of the liquid in the hydraulic main, as seen in the figure, are thus sealed, so that when one retort is opened, gas still bubbles up from the tubes of the others, and can only escape by the common exit tube *e*. From *e* it enters the cooler or condenser *f*; which generally consists of a series of vertical tubes, exposed to the air or surrounded by water, and in which a large quantity of volatile matter condenses. From the condenser the gas passes through *g* to the lime purifier, in which carbonic acid, sulphuretted hydrogen, and ammoniacal salts, are extracted from it, and thence by the pipe *m* it enters the gasometer *h*. It is then distributed through *q*, to the points where it is to be burned. *Parnell*.

Retorts. The retorts made of cast-iron and placed horizontally in the stack, are about 7 ft. long, 20 to 22 inches in greatest breadth, and 9 to 12 in. high in the middle. Cross sections of the principal

Fig. 75.



forms are given in fig. 75, *a* being semi-cylindric, *b* kidney-form, and *c* oval. *a* and *b* are the best forms, or *a* with the lower curve of *b*. A retort is charged by throwing in the coal from the front open end, and is closed by a flat plate of iron screwed fast and the seams clayed. The upright pipe from a retort sometimes curves over at the top, or more frequently by a double elbow, and then enters the hydraulic main. The retorts are built in brick-work, 3, 5, or 7 being arranged in one bed or stack. In large establishments there are several hundred retorts. The retorts are constantly kept at a red heat, which is the best for the distillation. The process requires from five to eight hours, according to the form of the retort and the nature of the coal. When the operation is complete, the lid is unscrewed, the remaining gas fired, to prevent explosion by mixture with the air, the coke raked out, and the retort recharged at once. Iron retorts are subject to rapid wear from several causes. An excess of air entering the fire tends to oxidize the iron; the sulphur (pyrites) in the coal forms sulphuret of iron, which melts off; at the high heat employed, both tarry matter and gas are partially decomposed, depositing thick layers of carbon on the interior, which, nearest to the iron, form layers of plumbago, rich in iron. In consequence of the wear of iron retorts, those of clay have been substituted with good effect.

They are made of clay, sand, and broken retorts pulverized, in the form of semicylinders (or better, concave-convex), which are jointed and luted together to form one retort. But the excess of heat required for clay retorts diminishing greatly the economy of the process, a combination of both clay and iron retorts has lately been successfully employed. According to Croll's plan, each stack or bench consists of an upper compartment, containing seven clay retorts, with the fire-place between the two lower ones of the series; and of a lower compartment, containing five iron retorts, heated by the fire, which, after playing below the clay retorts, descends to the back of the three upper iron retorts, passes to the front, descends to the two lowest, and again runs along them to the chimney. In this arrangement, a 260-lb. charge of coal is worked off in $4\frac{1}{2}$ hours, the iron retorts have proved more lasting than formerly, the clay retorts last as long, and there is a great saving of fuel, 24 pr. ct. of the coke produced being consumed, instead of 50 pr. ct.

From the hydraulic main, the gas generally enters the condenser, but it is sometimes washed previously, by being passed through vertical pipes, in which jets of water are playing. The coolers or condensers consist of vertical pipes, through a series of which the gas has to pass alternately upward and downward. Each alternate two are connected above, and alternately below. The deposited liquid from the gas collects in the iron boxes at the bottom of the pipes, and flows off at a certain height, so that the gas can only pass from one tube into another. In another form of condenser, the series of shorter tubes may be enclosed in an iron box, through which cold

Fig. 76.

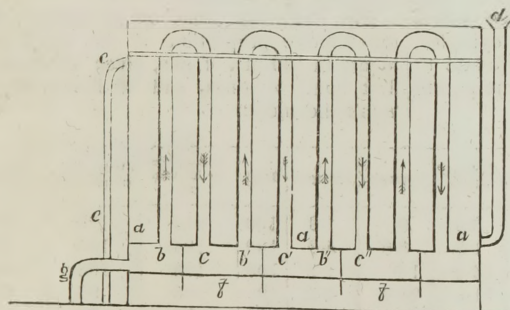
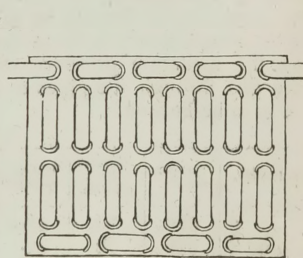


Fig. 77.



water is flowing, as shown in fig. 76. The tubes terminate in the plate *a*, and from this plate, between every alternate pair of tubes, a partition descends below the level, *f*, of the condensed liquid, which is always kept at the same height by the pipe, *g*, leading to the tarcistern. Cold water enters by the pipe *d*, and passes out through *e*. Fig. 77 is a view of the upper part of the condensing series. The arrangement given in fig. 74 is rarely employed. It consists of an iron box, with a series of iron shelves filling the interior, and each shelf, having a raised rim, capable of holding water. Water run upon the upper shelf flows over the others successively, and passes out at *t*. The gas entering at *v*, passes off through *s*.

The greater part of the tar and ammoniacal liquor are deposited in the condensers.

Purification. The lime purifier consists of cream of lime, or of slightly moistened slaked lime. Fig. 74 *g* is a wet lime purifier, into which the gas enters by *k*. This tube terminates in a disk with numerous perforations, through which the gas bubbles through the cream, the latter being stirred up by the agitator *l*, in order to bring fresh lime in contact with the gas and promote the absorption of the impurities. Sometimes two or three purifiers are successively used. The dry lime purifier consists of a series of trays of iron-grating, perforated plates, or of wicker-work, laid one above the other in a box, each con-

taining a layer of slaked lime, slightly moistened, through which the gas is made to pass. The wet is believed to be superior to the dry purifier, but less convenient. The action of lime is to absorb from the gas, by chemical action, sulphuretted hydrogen, cyanohydric, carbonic, muriatic and acetic acids, forming severally sulphuret, cyanide, and chloride of calcium, carbonate and acetate of lime. It retains also still further quantities of tarry matter and ammoniacal salts. Its greatest usefulness consists in removing sulphuretted hydrogen, which it should do effectually. But on the other hand, its use is attended with the disadvantage of setting free a quantity of ammonia, whose acids it retains. The disadvantage is not a serious one, but attempts have been made to remove ammonia by passing the gas from the lime purifier through a purifier containing a solution of alum, manganese vitriol, or green vitriol. The last are the best, since they remove also the last traces of sulphuretted hydrogen and prussic acid. A new method of applying them is to pulverize the crystallized salt finely, and spread it on trays like those of the lime purifier, moistening it slightly to increase the absorption. The gas is also passed through dilute sulphuric acid in leaden vessels, which effectually retains ammonia; and if this purifier be used before the gas enters the lime purifier, the quantity of ammoniacal sulphate is an important object of extraction, and the lime acts more readily on the balance.

After purification, the lime enters the gasometer, which is a wrought-iron cylinder, 30 to 50 ft. diameter, open at the bottom and closed at the top, and passing into a cistern of water, which seals the lower open end. It may be balanced by the weight *p*, fig. 74, attached to the chain *n*, passing over the pulleys *o*. But they are generally suspended at three points by weights, which nearly balance the cylinder, allowing the moderate pressure requisite to force the gas through the pipes to the points where it is to be burned.

Composition of Gas. The quantity and quality of gas obtained is differently stated, from the different kinds of coal used, the quantity subjected to test, the amount of heat, &c. The following table, calculated from Peckston's results, shows the difference in the quantity in cubic feet obtained from 1 lb. of coal, at a bright cherry-red heat. The experiments were made on large quantities of coal.

Name of Coal.	Cub. ft. gas.
Scotch cannel	5.29
Russell's Wallsend	4.62
Tanfield Moor	4.50
Wigan Ovall	4.00
Forest of Dean	3.43
Staffordshire, first kind	2.89
Pembry	1.87

The following table by Peckston shows the quantity obtained in eight successive hours from a chaldron of Newcastle coal, in 18 retorts.

In the 1st hour	2000 cub. ft.
2d "	1495 "
3d "	1387 "
4th "	1279 "
5th "	1189 "
6th "	991 "
7th "	884 "
8th "	775 "

In eight hours 10,000 "

The constituents of gas are given above in the tabular view of the dry distillation of coals. Of those constituents, olefiant gas, light carburetted hydrogen, carbonic oxide, and hydrogen compose the greater bulk of the gas. The illuminating power depends on the olefiant gas and the volatile hydrocarbons, which are condensable by chlorine.

The following table, by Dr. Henry, shows the relative proportion of the chief constituents in 100 pts. of gas, given off during the first hour, 5 hours, and 10 hours after the commencement.

Time of collection.	Specific gravity.	Absorbed by chlorine.	Light carb. hydrogen.	Carbonic oxide.	Hydrogen.	Nitrogen.	Total.	Vols. oxygen for 100 vols. gas.	Vols. carb. acid produced.	Spec. grav. after chlorine.
In 1st hour	650	13	82.5	3.3	0.	1.3	100	217	128	575
	620	12	72.	1.9	8.8	5.3	100	194	106	527
	630	12	58.	12.3	16.	1.7	100	196	108	533
After	5 hrs. 500	7	56.	11.	21.3	4.7	100	166	93	450
	10 hrs. 345	0	20.	10.	60.	10.0	100	78	30	345

Carburetted hydrogens are chiefly formed, but the illuminating part of these is but one-fifth during the first hour. After 5 hours the quality deteriorates, so that at the end of 10 hours the gas contains no illuminating power, and burns with a blue flame. The great increase of hydrogen, towards the last, shows that carburetted hydrogen is decomposed, as has been proved by Marchand, who passed olefiant gas through a red-hot tube, the heat of which was gradually increased to whiteness, and the resulting gases successively collected and examined for their relative proportion of carbon to 100 hydrogen. The following table expresses his results.

Hydrogen :	Carbon.	Nature and heat of the gas.
100	: 614....	Olefiant gas.
100	: 580....	Red heat.
100	: 533	
100	: 472	
100	: 367	
100	: 325....	Intense white heat.
100	: 307....	Light carb. hydrogen.
100	: 7. }	Continued white heat.
		Nearly pure hydrogen.

Henry observed that below a cherry-red heat, hydrogen, atmospheric air, and but little illuminating gas passed off. In fact, below a red heat, tar is the principal product,

and at a red heat, it is first formed, and then resolved by the heat into the gaseous products. A large quantity of the tar, however, escapes the action of the fire, and some arrangements have been made to convert a larger quantity of it into gas.

The presence of moisture in the coal has been found to exert an injurious influence on the quantity and quality of the gas. The action of steam upon olefiant gas, at a high heat, is to produce carbonic oxide, light carburetted hydrogen, and hydrogen; thus $C_2H_2 + HO = CO + CH_2 + H$. M. Penot considers that the 10 pr. ct. hygrometric moisture in coal in its ordinary state, deteriorates the illuminating power so much that the proportion of olefiant gas from such coal to that from dry coal is as 1 : 1.5. These results have been confirmed by experiments on a large scale.

According to some experiments, the luminous power of coal gas is diminished by too much purification, which may be inferred from the fact that this power is in a measure due to the content of naphthalic vapors, which are partly retained in the lime and other purifiers. Improvements of the process of purification are therefore probable and desirable. The illuminating power of all coal gas is far from being equal to what it would be if the gas contained more carbon. This result is hardly to be expected in the manufacture itself; but a

remedy for the defect has been proposed by Lowe, which is worthy of consideration. He proposed to pass the gas, shortly before its issue from the burner, through coal-naphtha (distilled coal-tar), which consists of hydrocarbons, very rich in carbon, and are dissolved by, or suspended in the gas. It was proposed to introduce this liquid into the gas-meter, or upon shelves in a box, or imbue sponge with it. If the practice were introduced, the orifices of the jets would have to be accommodated to the change.

Oil Gas. Refuse oils and fats may be resorted to for making illuminating gas. Since they contain less carbon and nitrogen, and more hydrogen, than coal, and contain no sulphur, the gas requires less purification; its preparation is therefore more simple, and iron retorts are used. The following is a comparative view of the ultimate composition of cannell coal and an average of several oils and fats.

	Carbon.	Hydrogen.	Oxygen, &c.
Coal	85	6	9
Fat	80	11	9

The following table by Dr. Henry shows the degree of heat adapted to making gas from oil, as well as the superiority of the gas over that from coal, as shown by its density and richness in olefiant gas. Train oil was used.

Temperature.	Spec. grav. of gas.	Absorbed by chlorine.	Light carb. hydrogen.	Carbonic oxide.	Hydrogen.	Nitrogen.	Total.	Vols. oxygen for 100 vols. gas.	Vol. carb. acid produced.
Dull red.....	906	38.	46.5	9.5	3.	3.	100	260	158
Higher heat.....	758	22.5	50.3	15.5	7.7	4.	100	220	130
Bright red.....	590	19.	32.4	12.2	32.4	4.	100	178	100
	464	6.	28.2	14.1	45.1	6.6	100	116	61

Fig. 78.

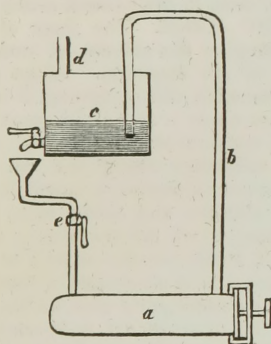
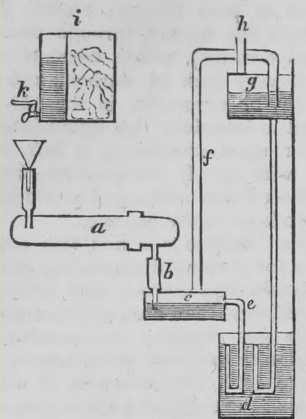


Fig. 78 represents the arrangement of an oil-gas retort. *a* is the retort, filled with fragments of brick or coke, in order to expose a large heating surface to the oil; *b* is the tube conveying the gas, together with empyreumatic oils and unchanged oil, into the reservoir, *c*, which corresponds somewhat to the hydraulic main, where the greater part of the vapors condense, and the gas passes off through *d*. Fresh oil also flows from a reservoir into the main *c*, and the mixed liquid descends again through *e* into the retort. There is therefore little loss from tarry and other empyreumatic

matter in distilling oil, and the operation differs further from that with coal in its uninterrupted continuance, the retorts being opened once in two or three weeks to charge with fresh coke or brick. One gallon of whale oil produces 90 cub. ft. of gas; of palm oil, 95 cub. ft. According to some authorities, 1 gall. will produce as much as 175 cub. ft., but it probably has less illuminating power. The illuminating power of oil gas is to that of the best coal gas as 2 : 1. The vaporous constituents of oil gas are somewhat similar to those of coal gas. See the compounds of carbon and **HYDROGEN**. Oil gas may be conveniently made from refuse fats, where small quantities of gas are required, and economically, where coal is not readily obtained. In this manner some of the steamers on the western rivers are supplied with gas from the refuse fat of the kitchen. A gas is prepared at Rheims from the fat of soap-water which has been used to free woollens from grease. The soap-water is treated with sulphuric or muriatic acid, to neutralize the alkali, when the fats collect on the surface of the liquid, and are remelted in water with a little sulphuric acid to effect clarification. The filtered fat is then treated with crude soda to make soap, and the deposited residue, containing much fat, is distilled in retorts like rosin.

Rosin Gas. Fig. 79 represents the apparatus for making gas from rosin. The retort *a* is

Fig. 79.



charged with coke or brick, and when heated to bright redness, melted rosin or a solution of rosin in rosin-tar, is allowed to flow into it. The rosin-tar and gas pass out below through *b* into *c*, where the rosin-tar collects and flows off through *e* into *d*. The gas passes up through *f* into *g*, where more vapor condenses and flows through a syphon tube into *d*. The undensified gas passes through *h* into the gasometer. To charge the retort with rosin, 8 or 10 lb. of rosin for every gallon of the oil from *d*, is introduced into the vessel *i*, where the whole is melted by the waste heat of the furnace below, and strained through a wire-gauze screen, which divides the vessel into two compartments. The melted mass is let into the retort by the stopcock *k*. One pound of rosin may yield 10 to 20 cub. ft. of gas. Its illuminating power is to that of coal gas as 3 : 2, and to that of oil as 3 : 4.

Other sources of gas. In the distillation of wood for pyroligneous acid, a large quantity of illuminating gas is produced, which is usually burned under the retorts as fuel for the distillation. See ACETIC ACID. In the distillation of animal matters for bone-black, and for prussiates by the older process, a large amount of an oily tar and gases are generated, the former of which has been employed for conversion into light-gas. See manufacture of prussiate of potash under CYANOGEN. It is asserted that by passing steam through iron tubes, filled with anthracite (coke) and heated to bright redness, light-gas is produced. With equal equivalents of carbon and water, the result should be carbonic oxide and hydrogen; $C + HO = CO + H$; with 2 eq. carbon and 1 eq. water, the result would be carbonic oxide and olefiant gas; $C_2 + HO = CO + CH$; therefore, with 3 eq. carbon and 2 eq. water, the result would probably be $C_3 + 2 HO = 2 CO + CH + H$, or $2 CO + CH_2$. Sellique's new process is partly based upon this catalysis. Three upright cylinders, heated to redness, are filled, the first two with charcoal, and the third with chain and scrap-iron. A small stream of water flows into the first cylinder, where it is converted into carbonic oxide and hydrogen (probably with some marsh gas, CH_4), and then through the second, where it probably

takes up carbon, and is a mixture of carbonic oxide, marsh gas, and hydrogen. (1st, $C_2 + H_2O = 2 CO + H_2$; 2d, $2 CO + H_2 + C = 2 CO + CH_2$.) From the second cylinder it passes into the third, filled with iron. Into this cylinder a stream of oil is allowed to flow (formed by the previous distillation of bituminous shale of Autun in France), and by the reaction of the gases with the vapors of this oil the new light-gas is produced. The bituminous shale yields 10 to 20 pr. ct. of oily matter, two-thirds of which are an oil of spec. grav. 0.766 to 0.810, which is used for the production of gas. According to the statements of those who have examined the process and its results, 1 lb. of the shale-oil, treated in the usual way (for rosin or oil gas), will yield 15 to 28 cub. ft., but by the above process 86 cub. ft.; the gas deposits no condensable vapors when cooled down to -13° ; there is no deposition of carbon on the iron in the third cylinder. Peligot found in 99 vols. of the gas, 56 carbohydrogens, 28 carbonic oxide, and 15 hydrogen. The oil being described as similar to a resinous oil, we may assume that it is mainly composed of C_5H_4 , and then the reaction would be as follows: The gas from the second cylinder ($2 CO + CH_2$) + $C_5H_4 = C_6H_6 + 2 CO$, or olefiant gas and carbonic oxide. The free hydrogen arises from the decomposition in the first cylinder, the marsh gas from the second; and a portion of both escaping composition in the third cylinder, we have a gas nearly of the composition ascertained by analysis. The spec. grav. of the gas is 560 (air = 1000). See ILLUMINATION for the modes of burning gas for light, and ANALYSIS for its use as fuel. See also ACETIC ACID, AMYL, BONE-BLACK, COAL, COKE, CYANOGEN, DRY DISTILLATION, LAMP-BLACK, with the articles referred to in the table of the dry distillation of coal, in the present article.

GASTRIC JUICE. The juice of the stomach, acting as the solvent of food and the promoter of its digestion. When collected from the stomach during fasting, it is neutral, but at other times is acid in its reaction. The principal constituents of the acid juice are *Pepsin*, a substance resembling salivary matter (osmazome?), mucus, occasionally a little albumen, alkaline and earthy salts, and free acids, among which are the butyric, &c.

Blondlot attributes the acidity to the presence of some acid phosphate of lime, and not to acetic or chlorohydric acid, as has been asserted. The more recent researches of Bernard and Barreswil (*Comptes Rendus*, 1844) show that it is attributable to lactic acid. These chemists did not find either chlorohydric or acetic acid, but detected a minute portion of phosphoric acid, which they considered a secondary product from a reaction of the lactic acid upon the phosphates contained in the juice.

The digestive property of gastric juice is most probably due to the union of two principles inseparable in their action;—1st, to a peculiar organic matter, *Pepsin*, acting after the manner of ferments, and at a temperature of 50° to 104° , higher than which last degree it loses its power; and 2d, to a substance with

acid reaction. B. and B. do not consider the acid as indispensable to the process of digestion, but they think with Blondlot, that if an acid reaction is requisite, the kind of acid producing it is unimportant. It loses, it is true, its digestive powers when neutralized by alkali, but the same result follows when it is heated nearly to 212° , because of a modification of one of its constituents, and not through loss of acidity, for this latter is neither destroyed nor impaired.

Blondlot's experiments as to its action upon simple and compound aliments (*Comptes Rendus*, 1843,) have been confirmed by Payen (*Ch. Gaz.* 1, 728), who in some further researches discovered an active substance analogous to pepsin, which he termed Gasterase.

Pepsin. A secretion of the stomach, found by Schwamm to constitute the essential portion of the gastric juice, and so termed by him from *pepsis*, digestion.

Prop. Wasmann was the first chemist who isolated it. Vogel prepared it by mincing the glandular membrane of the fresh stomach of a hog, immersing it in cold distilled water at intervals of twenty-four hours, and renewing the water until a putrid odor was perceptible. From the aqueous infusion thus obtained, the pepsin, mixed with much albumen, is precipitated in white flocculæ by acetate of lead. This deposit diffused through water must be decomposed by a stream of sulphuretted hydrogen gas. The filtered liquor then contains pepsin and acetic acid, while coagulated albumen and sulphuret of lead remain in the filter. The solution, evaporated below 95° and treated with absolute alcohol, lets fall a milky precipitate, which, when dry, is a yellowish viscid mass. The acetic acid which it contains is effectually removed by heating the pepsin for some hours in a salt-water bath, by which means a white powder, soluble in water, is obtained.

Prop. Its formula, nearly according with Vogel's analysis, is $C_{48}H_{32}N_8O_{10}$. It is insoluble in absolute alcohol and ether, and forms compounds with the acids. A small quantity of acid precipitates it from its solution, but the deposit is redissolvable in an excess, and again precipitable by a further addition of acid, except with the acetic, which gives no second precipitate. When slightly acidulated it dissolves the protein compounds. Precipitated from a concentrated aqueous solution by anhydrous alcohol, it is said to lose its digestive power. It is not precipitable by ferrocyanide of potassium.

Liebig denies the existence of pepsin as a distinct compound, and attributes the solvent power of gastric juice to the gradual decomposition of a matter dissolved from the membrane, aided by the oxygen introduced with the saliva.

GAULTHERIA PROCUMBENS. Syn. Wintergreen, Partridge-berry. An indigenous plant, which yields a volatile oil much used as a flavoring ingredient.

Oil. As found in commerce is yellowish, but when rectified, becomes colorless, and retains an acid reaction, though presenting the composition of a neutral ether. Its spec. grav.

is 1.18 and upwards, and its boiling point 432° . Proctor (*Am. Jour. and Ann. Chym.*) first showed its relation to the salicin series; and Cahours (*Comptes Rendus*, 1843) found that of the two oils which it yielded by heat, that passing over lastly is the *Salicylate of Methyl*; the other he termed *Gaulthérylen*.

Salicylate of Mether. *Spirylsaures Methyloxid.* (Berz.) Form. $C_{16}H_8O_6 = C_2H_3O, C_{14}H_5O_5$. A colorless aromatic liquid, boiling at 435° , and yielding a vapor of spec. grav. 5.420. In water it is only slightly soluble, but alcohol, ether, oils of terpentine and lemon dissolve it readily. The aqueous solution takes a bluish tint upon the addition of a subsalt of iron. By distillation with potassa there is formed in the retort a product, which, when treated with water and mineral acid, yields an abundant precipitate of salicylic acid. By the action of gradual additions of fuming nitric acid, salicylic mether is transformed into indigotic or anilic mether.

Spirylic mether unites with bases, like spirylic ether, without the spirylic acid losing its conjugate, mether; and its salts may be termed methylic spirylates or salicylates. Cahours terms them gaultherates. The salts of potassa, soda, and baryta, are crystalline. Like the spirylic acid itself, this conjugate acid is inclined to exchange 1 or 2 eq. hydrogen with 1 or 2 eq. bromine or chlorine. As neither an excess of chlorine or bromine removes more than 2 eq. hydrogen, Berzelius infers that spirylic acid is a conjugate acid, composed of $C_{10}H_3O_5 + C_4H_2$, that the former is probably pyromucic acid, and that bromine replaces one or both equivalents of hydrogen in the conjugate, C_4H_2 .

Gaulthérylen. A carbo-hydrogen, $C_{10}H_8$, isomeric with spts. terpentine, forming the lesser portion of the oil of wintergreen. It is colorless, boils at 320° , and yields a vapor of spec. grav. 4.920. Its odor is similar to that of pepper. Nitric acid transforms it into a resinoid mass; and chlorine and bromine into viscous products, their hydrogen being evolved, and the halogen uniting with the residue.

Proctor (*Am. Jour. Pharm.*, 1844) considers the essence of the *Betula lenta* identical with that of the *Gaultheria procumbens*, and as an immediate product in the latter, whilst in the former it is generated, secondarily, by the action of a substance similar to synaptase or emulsin, upon *gaultherin*, an immediate principle of the *Betula lenta*. The gaultherin is obtained by extracting the bark with alcohol, distilling and treating the residue with water, this aqueous solution with hydrate of lead; the clear liquor is evaporated to dryness, reated with alcohol, and evaporated to a syrup, which dries to a gummy mass. The gummy mass, by distillation alone or with dilute sulphuric or muriatic acid, yields oil of gaultheria. If boiled with baryta, filtered, exactly precipitated, the solution saturated with carbonate of lead; this solution precipitated by sulphohydric acid, and the clear liquor is evaporated, a crystallized acid is obtained, gaultheric acid, which is soluble in alcohol, difficultly in ether, forms gummy salts with bases, and oil of gaultheria by distillation with dilute sulphuric acid.

GAY-LUSSITE. Min. Cryst. Oblique

Rhombic. Cleavage perfect parallel to vert. prism, *g.* $H. = 2-3$. $G. = 1.92-1.99$. Yellowish white, vitreous; translucent, with double refraction; very brittle, with conchoidal fracture and grayish streak; slightly soluble in water.

Chem. Rel. Alone in a tube, it gives off much water, and has an alkaline taste and test; it fuses to a cloudy bead, and behaves to the fluxes like calcareous spar. After ignition, water dissolves out all the carbonate of soda, and leaves carbonate of lime. It is readily soluble in acids with effervescence. Form. $\text{NaO}, \text{CO}_2 + \text{CaO}, \text{CO}_2 + 5 \text{HO}$.

Local. Lagunilla, near Merida, in Maracai-bo, S. A., at the bottom of a lake covering **TRONA**.

GEDDA GUM. Syn. Jedda. Imported from Alexandria. The red pieces of *Gum Arabic*.

GEDRITE. *Min.* Fibrous or lamellar; clove brown; submetallic; tough; streak grayish. $H. = 5$. $G. 3.36$. Fuses readily to a black enamel. It is probably Epidote (*G. Rose*) or Hypersthene (*Rammelsberg*). Occurs near G  re, in Pyrenees.

GEHLENITE. *Min.* Stylobite. Cryst. Quadratic, cleavage imperfect parallel to end-plane. $H. = 5.5-6$. $G. = 2.916-3.06$. Gray; resinous, subvitreous; subtranslucent, opaque; fracture uneven, splintery; streak white, grayish white.

Chem. Rel. Fusible with great difficulty in very thin fragments to a gray glass; difficultly soluble in borax and mic. salt; decomposed by muriatic acid. Form. $3 (3 \text{RO}, \text{SiO}_3) + 3 \text{R}_2\text{O}_3, \text{SiO}_3$. ($\text{RO} =$ lime and magnesia and $\text{R}_2\text{O}_3 =$ alumina and peroxide of iron.) Closely allied to, and by some united with Humboldtite.

Local. Mt. Monzoni, Fassathal.

GEIN, GEIC ACID. See **HUMUS**.

GELATIN. *Chem. Tech.* Syn. Ichthyocolla, Isinglass, Glue. A solid transparent colorless corneous substance, which forms with boiling water a solution that on cooling takes the consistence of a jelly. In its natural state, and as existing in the cellular tissue, bones, tendons, &c., to which in their woof it serves to give form, it has the name of *Histose*. This latter, being treated with boiling water and dried, becomes gelatin; but previous to this action, bears the same difference from the latter, in appearance and properties, as can exist between a completely organized body and its constituent elements in a state of complete desiccation.

Chondrin, which is the gelatin of cartilages, is analogous in many properties, but, unlike gelatin proper, is precipitated by acids, alum, and the salts of lead. *Glue* is the technical term for the gelatin of bones, hoofs, and hides, *Isinglass* for that from the air-bladder and entrails of certain fishes, and *Size* for the less tenacious and adhesive aqueous extract of parchment scraps and several animal membranes.

Prop. Formula of ichthyocoll, sclerotica, &c., $\text{C}_{48}\text{H}_{41}\text{N}_{75}\text{O}_{18}$; of chondrin, cornea, &c., $\text{C}_{48}\text{H}_{40}\text{N}_{6}\text{O}_{20}$; of arterial, $\text{C}_{48}\text{H}_{38}\text{N}_{6}\text{O}_{16}$. (*Mulder, Liebig, Scherer, &c.*) It is flexible and elastic when perfectly dry, and breaks with a vitre-

ous fracture, but is very tenacious when moist. At 212° it softens and melts, but at a higher temperature is decomposed into animal products and a slight residue of earthy matter. In cold water, at the ordinary temperature, it swells up and loses its solidity; but if heated, when thus impregnated with water, to 120° or 140° , it becomes so minutely suspended as to give the appearance of a perfect solution. It is insoluble in alcohol and ether, and anhydrous alcohol precipitates the gelatin from its pseudo solution in water. With tannin it forms a very intimate union (see **TANNIN**), an elastic mass similar to, and of the same composition of, but not transformable into **LEATHER**, owing to the destruction of its organized form. Mulder, who has examined the subject, considers the compounds of gelatin and tannin as definitely proportioned.

Gelatin is transformed by nitric acid into oxalic acid; by sulphuric acid into *Sugar of Gelatin*, or glycocoll, *Leucin*, and sulphate of ammonia. Hydrochloric acid, by the abstraction of minute earthy impurities, renders it more hygroscopic and readily soluble, especially that extracted from bones. Potassa converts it into a mixture of sugar of gelatin and leucin, and though not of the protein series, it may nevertheless contribute to the nutrition of the gelatinous tissues. Bi-chloride of mercury coagulates and renders it insoluble, but an excess of gelatin dissolves the mercurial product as fast as it is formed. It is also precipitated from its apparent solution by the nitrate of mercury, and chloride of tin; but alum, sulphate of iron, the neutral and basic nitrates of lead, are without action. Sulphate of platinum, which throws down brown flocks, was proposed by Davy as a test for gelatin.

The white curdled product formed by the action of a current of chlorine gas upon the pseudo solution of gelatin, and formed, according to Mulder, of 4 eq. of humid gelatin and 1 of chlorous acid, is but slightly soluble in water, and less so in acetic acid. Neither chlorine nor bromine give an analogous product.

Products of decomposition. By long digestion at a temperature above 212° , gelatin loses its gelatinizing power, and forms on evaporation a gummy mass readily soluble in cold water.

By the action of chromic acid, a series of products is generated. (*Persoz and Marchaud.*) The best proportions for oxidizing gelatin by chromic acid are, 2 pts. of glue, 8 of bi-chromate of potassa, 15 of sulphuric acid, and 50 of water. (*Chem. Gaz.* vol. iv. 10, and v. 9.) Among these products are acetic, valerianic, benzoic, prussic, and formic acids, and two volatile oils, one *Valeronitrile* (C_{10}NH_9), of spec. grav. 0.81, soluble in alcohol and ether, and boiling at 257° , and the other *Valeracetoneitrile* ($\text{C}_{26}\text{H}_{24}\text{N}_2\text{O}_6$), of spec. grav. 0.79, and boiling between 154° and 158° . *Schlieper.*

Glycocoll. Syn. Gelatin Sugar.

Prep. and Prop. Obtained from the solution of gelatin in concentrated sulphuric acid, by dilution with water and saturation with chalk. It can also be prepared by the decomposition of hippuric acid, which on being boiled with a strong acid, yields it together with benzoic

acid. (Dessaigues.) Form. $C_4H_8N_2O_6, 2HO$, (Mulder). $C_4H_4NO_3, HO$, (Horsford). $C_4H_5NO_4$, (Dessaigues, Laurent). Its analogy with alcar-gen (see Κακονυλ) is evident by a comparison of their formulas (alcargen = $C_4H_5AsO_4$, glycocoll = $C_4H_5NO_4$). (Hint, in *Am. Jour. Sci.*, Sept. 1847.) Dessaigues observed that hippuric acid was benzoic with a conjugate of the composition of glycocoll. Glycocoll crystallizes in colorless rhomboidal prisms, of a sweetish taste, which fuse at 352° , with decomposition, into ammoniacal products, are soluble in 4-35 pts. of cold water, almost wholly insoluble in ether and absolute alcohol. With hydrochloric acid it forms one neutral (Gl, HO, HCl) and four crystallizable basic salts. Their formulas are, 1. Gl, HO + Gl, HCl; 2. Gl, HCl + GlHO, aq.; 3. 2 (Gl, HCl) + Gl, HO, aq.; 4. 2 (Gl, HCl) + Gl, HO. With sulphuric acid it gives an anhydrous (Gl, SO_3), a neutral hydrated (Gl, SO_3 , HO), and three basic salts, the formulas of which are, 1. 2 (Gl, HO, SO_3 + HO) + Gl, HO; 2. 2 (Gl, SO_3) + Gl, HO; 3. 2 (Gl, HO, SO_3) + Gl, HO.

The nitrate of glycocoll, called by Braconnot *Nitrosaccharic Acid* because of its acid taste and reaction, takes the form either of tabular or acicular crystals, which do not become moist on exposure. Horsford's analysis gives Gl, HO + NO_5 , HO = $C_4H_6N_2O_{10}$ as their composition. It unites with oxalic acid, Gl, HO, C_2O_3 ; with acetic acid, Gl, HO, AcO_3 + 2 aq.; with tartaric and palmitic acids. It unites with hydrates of potassa and baryta, with oxides of silver, copper, and lead; Gl, HO, PbO, and Gl, HO, CuO. It combines with chlorides of potassium, Gl, KCl, of sodium, of barium, Gl, BaCl, 2 aq., of tin and of platinum, Gl, Pt, Cl_2 + 2 aq.; further with nitrate of silver, bisulphate of potassa, Gl, SO_3 + Gl, KO, SO_3 , with sulphate of ethyl, Gl, HO + AeO, SO_3 , with urate of ammonia, Gl, Uro_6 + NH_4O , Uro_6 .

Upon examining the behavior of glycocoll, it seems to present both acid and basic characters. It is isomeric with fumarate or aconitate of ammonia. Horsford, who observed the former, endeavored to obtain the acid and ammonia from it, but neither potassa nor baryta would throw off ammonia. By repeated evaporation with sulphuric acid, he obtained a crystallized body with the formula, Gl, HO, SO_3 + NH_4O , SO_3 , aq., from which it would appear (by the then reaction with potassa) that sulphate of ammonia was produced. He observes that "glycocoll is a salt, the base of which is ammonia, and whose acid possesses a formula resembling that of fumaric acid." It is, however, more probable that glycocoll is a doubled ammonia, whose conjugate is isomeric with fumaric acid, but not that acid; that it forms compounds both like ammonia and oxide of ammonium. Calling the conjugate, C_4HO_3 , Cg, the formula of glycocoll is Cg, NH_3, HO ; that of the anhydrous sulphate, Cg, NH_3, SO_3 , corresponding to sulphate of ammonia, and the hydrous sulphate is Cg, NH_3O, SO_3 , corresponding to sulphate of oxide of ammonium. The first basic hydrochlorate is Cg, NH_3, Cl + Cg, NH_3, HO . Another, but less likely view, is that glycocoll is a compound body

similar to ammonia, and that it acts with 1 eq. HO like a metallic oxide, the hydrated sulphate being then $C_4H_5NO_4, SO_3$. The study of its decompositions will probably confirm the view that it is a conjugate ammonia.

Uses and preparation. Under the form of Glue, gelatin performs a most important part in the arts, as a constant aid to the joiner and artificers generally, whilst more refined, as *bone glue*, it is used for all the nicer operations of cementing the finer and costlier specimens of handicraft, for stiffening bonnets, and in the fine arts for painting in water colors.

In domestic economy it is used, under the forms of soup and jelly, as an aliment; but though experiments seem to show that when mixed with fibrous, albuminous, and caseous substances, it becomes nutritive, this conclusion is yet doubtful, for the theory of respiration proves that histose, which produces the gelatin, has accomplished its part in the animal organization, and can no longer afford sustenance thereto. One fact, however, seems positive, and that is, its inability alone to yield nourishment to carnivorous animals. The feeble nutritive power of a gelatinous matter seems to be owing to the destruction of its organization.

"Cooper's Isinglass," a popular article for making extemporaneous jelly and blanc-mange, is the consolidated gelatin extracted by steam from fresh bones, perfectly clean, and freed of fat by previous boiling. Beef bones are the best raw materials. A proportion of calf bones renders the gelatine milky; those of the hog produce a blackish froth which is difficultly separable, and those of sheep impart a very perceptible suety odor. Roper's process for preparing this alimentary gelatin is as follows: The cylinder of a digester similar to that represented by fig. 80, is charged with bones broken into small pieces or reduced to dust, and 6 gallons of water are added to each hundred-weight of bones; the digester is then closed, and steam admitted from a boiler at a pressure of 20 lbs. per square inch; after the expiration of an hour the pressure is gradually raised to 32 lbs., which is continued for $3\frac{1}{2}$ hours, and the charge of gelatin is then drawn off; if the dust of bones or ivory has been used, gelatin is pressed out of the charge after its withdrawal from the digester; but this is not requisite when the bones have been only broken into pieces, and placed in a strong woollen fabric. The gelatin is run into shallow tins or pans, and afterwards dried on nets in the usual way; it is then well washed, and melted with an equal weight of sugar, flavored with essence of lemon when for jellies, and with essence of almonds when for blanc-mange; and these matters are melted in a digester by steam. When essence of lemon is used, it is in the proportion of 2 dr. to every 3 lbs. of gelatin; it is first mixed with the sugar, which is added to the gelatin after the latter has been melted with lemon-juice, in the proportion of 18 oz. of lemon-juice to 3 lbs. of gelatin. Essence of almonds is used in the same proportion as the essence of lemon, but water is substituted for the lemon-juice. Other essences or essential oils may be used in a

similar manner. The gelatin, prepared as above, is placed in jars for sale. Jellies may be quickly made therefrom by the use of boiling water, containing the white of an egg, adding wine according to taste. To make a blanc-mange only boiling milk is required. *Ch. Gaz.* Dec. 1845.

The digester above referred to is the contrivance of D'Arcet, in which the gelatin is extracted by water in a state of tense vaporization. It is shown by figs. 80 and 81.

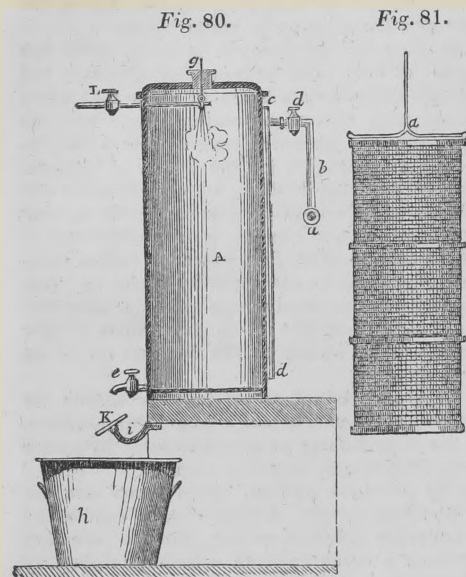


Fig. 80 is a vertical section of the apparatus. A is an hermetically closed cast-iron cylinder, into which the steam is conducted; a the main steam-pipe; b a vertical pipe conveying the steam into the cylinder A; c c branch-pipes leading the steam to the bottom of the cylinder; d a stopcock upon the pipe b, for regulating the entrance of the steam into the interior of the cylinder. (The tubes and the cylinder should be wrapped around with woollens, so as to retain their heat and prevent their cooling.) e is the stopcock for the discharge of the gelatinous solution; f the cover of the cylinder, which is fastened to the cylinder, so as to prevent the escape of any of its contents; g a tubulure in the cover for the reception of a thermometer; h a tub to receive the solution as it is formed; i a gutter for conveying into another vessel the grease which is run off in the commencement of the operation; K another gutter, moving on a pivot, which receives the liquid as it runs from the cock e, and empties it into the tub h, or into the trench i; l a tube for feeding the interior of the cylinder with fresh water; m a movable adjustment attached to the pipe l for regulating the quantity of water and preventing a too great elevation of temperature in the interior of the apparatus.

Fig. 81, elevation of the interior basket, made of wire-cloth. This basket, or cage, receives the cleansed and crushed bones, and is enclosed in the cylinder A; a is the handle with which, by means of a pulley, it is lifted

or lowered, to be emptied or charged. Four or more of these machines make a series, and the boiler which feeds them with steam should carry a pressure of 4 lbs. to the inch.

It is important, in using this apparatus, that the action of steam be not too prolonged; otherwise a portion of the animal matters will be converted into ammoniacal products. Moreover, the greatest cleanliness must be observed in order to prevent any tendency to putrefaction. To obtain a stiffer jelly, the cylinder containing the bones must be enclosed with woollen stuff, and when the grease ceases to drop, the injection of cold water is suspended, and the evacuating cock opened only hourly, and then but sufficiently to allow the exit of the gelatinous solution without any escape of steam.

A well-conducted operation gives the following average yield of 100 pts. of bones.

Gelatin	28.204
Grease	7.216
Residue.....	64.580

The residue contains, phosphate and carbonate of lime, $\frac{9}{100}$; animal matter unacted upon by steam, lime-soap, and free grease, $\frac{1}{10}$. This residue, when added to new bones, gives, by calcination in close vessels, an excellent animal charcoal; or it can be used for the manufacture of phosphorus, or as a manure for fertilizing soil for the growth of cereals. The grease obtained in the first stage of the operation is an excellent ingredient for fine soaps and pomades.

The gelatinous solution prepared by this apparatus contains 5 oz. of gelatin per gallon. By rapid evaporation, in shallow pans, at a properly regulated temperature, it becomes sufficiently concentrated to be transferred to moulds, whence, after a proper repose, it is taken, divided into thin layers, and dried in the usual manner.

For the preparation of nutritious soups, to which this apparatus is particularly adapted, beef bones only should be used, and these should be perfectly fresh and clean, and freed of adherent skin and cartilage. One hundred and thirty-two pounds of bones treated as above for 24 hours, yield 237 galls. of solution, which require 317 lbs. of coal in their preparation.

The gelatinous solution, when prepared for soup, should contain 75—90 grs. of gelatin per pint. To prepare 105 galls. of meat soup with the gelatinous solution thus prepared, take of

Gelatinous solution	105 galls.
Meat, with its bone.....	44 lbs.
Carrots	22 "
Eschalots	11 "
Turnips	5.5 "
Celery	1.0 "
Salt	17.5 "
4 Cloves.	

These materials, placed in an autoclave (DIGESTER) and heated for five hours, yield an excellent soup, and a still better if the proportion of meat is increased to 25 pr. ct.

Glue. Is impure and perfectly dry gelatin. When minutely suspended in water, it is very

tenacious, and hence its fitness as a cement for joints. It can be prepared from all animal substances which yield gelatin by boiling with water, but the materials most used in the arts for furnishing the *common glue*, are the waste pieces of skins, old ceroons, damaged hides, &c. A better quality and more transparent glue is made from the tendons of cattle and horses, and a still finer and whiter kind from bones. Glue improves by age, and that is best which, after being soaked in water, swells without melting, and resumes its dimensions upon drying. Bone glue obtained by acids ranks first in quality; that extracted from bones by steam is the most inferior kind, being more or less soluble in cold water. The glues from the skins of wild animals occupy the second grade, and are followed by those obtained from the hides of domestic animals. *Marine glue*, though it contains no gelatin, owes its name to its tenacity and property of cementing joints which retain their adhesiveness even under water. Dumas, to whom we are indebted for the following process, gives the annexed table of the per-centage of glue which is yielded by certain kinds of raw material.

Scraps of glove skins, freed from grease and fleshy particles	44 to 46
The epidermis of the hides used for the manufacture of belts	30
Buenos Ayres scraps and the casings of boxes imported from Brazil, &c.	56 to 60
The large tendons of cattle shanks, mixed with the small bones and portions of muscle, &c.	35
Parchment scraps.....	62
Tanners' clippings and refuse, consisting of sheep and calves' ears, the feet and tendons, and small bones (when clean)	38 to 42
Indigo and bark ceroons.....	50 to 55
Calves' heads, from the tanneries...	44 to 48
Hare and rabbit skins	54

In order to prevent the fermentation of these materials in their fresh state, and at the same time to diminish their cost of transportation, they undergo a preliminary treatment, consisting of 15 or 20 days' maceration in milk of lime, several times renewed during the interval. At the end of this time they are taken out and spread in the open air to dry. This desiccation is hastened by repeatedly turning the material so as to present fresh surfaces; and when it is complete, the material may be bagged and sent to the factory.

The lime-water dissolves the blood and soft portions, attacks the epidermis and predisposes the tissue to a more rapid transformation into gelatin. Its chemical action is not well ascertained.

Before being used, the glue materials must again be immersed in a weak milk of lime, so that they may be freed of some more of their soluble matter. When they are well soaked, they should be well and repeatedly rinsed in fresh water, to remove the excess of lime, and then placed upon sloping slabs of stone, or better upon hurdles, to drain, and turned over from time to time, until the free lime becomes

completely carbonated, because in its caustic state it would alter the gelatin at the moment of its extraction.

The glue pieces thus prepared are immediately conveyed to the boiler, which is either of copper or iron, and placed immediately over the fire, so that its bottom, which converges inwardly, the better to resist the heat, may be equally exposed to the flame. Resting upon the bottom is a stopcock for the evacuation of the gelatinous solution. Above the true bottom there is another false bottom, cullendered and movable. It is supported by flanges or tripods of 3 to 6 inches height, and serves as a preventive of direct contact of the materials with the heated bottom of the caldron, and hence any injury by scorching. The caldron, being heaped to overflowing with glue pieces, is then filled two-thirds of its height with water. If the water is previously heated the process is hastened, and with less fuel. As soon as ebullition commences, the contents of the caldron begin to settle down gradually, until at last they become completely submerged in the liquid, which has proportionably augmented in volume. Frequent and thorough stirring is indispensable during the ebullition, which should be gentle and uniform, and sometimes in the early stages of the process a portion of the liquid is drawn from the bottom of the kettle and poured again over its contents.

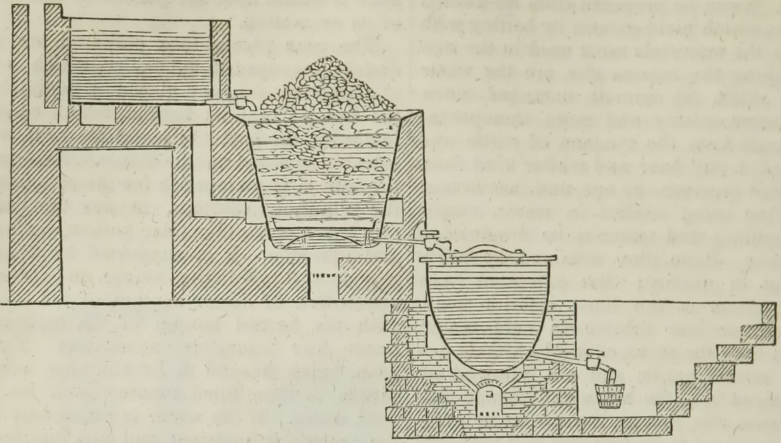
The operation is then completed either by fractioning the products of the solution so that they may remain the least possible time exposed to the fire, or else by adding at once the whole quantity of water necessary to dissolve the gelatin, and prolonging the ebullition until the material is entirely melted. The products of the first method are more tenacious and of better quality;—those of the latter, though sufficiently good in appearance, are inferior, for the gelatin which is extracted in the first hours of the operation remains exposed to a boiling temperature until the completion of the boiling, and thus is inevitably altered. The solution therefore should be drawn off in successive portions, commencing as soon as a drawn sample will form a stiff jelly on cooling. This mode of drawing the solution subdivides the resulting glue into several grades of quality, decreasing in value from the first drawing.

When this mode of manufacture is adopted the following convenient arrangement should be adopted. Fig. 82 represents the apparatus, which consists of three caldrons, upon as many different levels. The lower caldron is a water-bath, which serves for the settling and clarification of the glue; the second caldron contains the materials to be acted upon; and the upper, heated by the waste heat of the chimney, serves as an economical reservoir for hot water.

As soon as the gelatinous solution is sufficiently concentrated, and becomes jelly-like on cooling, the fire must be withdrawn, and after 15 minutes' repose the contents of the boiler slowly drawn off through the exit cock into the lower or water-bath kettle previously heated to 212°, and therein left to settle for 4 or 5 hours before being transvased to the cooling

GELATIN.

Fig. 82.



troughs. In the mean time the grounds or residue in the caldron are again treated with hot water from the upper reservoir, and the ebullition continued until the second solution becomes sufficiently concentrated to form a thick jelly on cooling. Finally, this operation is repeated a third time; but as the liquid then obtained is not sufficiently dense to form glue, it consequently must be strengthened by boiling with a portion of fresh parings, or else it may be retained as the liquid for the second ebullition in the working of the next lot of materials. If it is preferred, they can be rapidly evaporated to form an inferior quality of glue. The exhausted residues are immediately withdrawn from the caldron, and pressed until they cease to yield liquid. These runnings should be mixed with the liquid of the third boiling. Finally, when this last made solution is sufficiently concentrated, it is clarified by lively agitation with one five-hundredth part of powdered alum, and then left to settle for four or five hours previous to decantation.

The three successive boilings give three different qualities of glue.

The cooling boxes into which the clarified glue is transvased should be of deal wood, lightly jointed, and of a rectangular form, slightly converging towards the bottom, so as allow the more ready detachment of their contents. After being well cleansed, and ranged upon a level, they are filled to the brim through large funnels with strainer cloths affixed to their barrels. The boxes are placed upon a perfectly clean stone flagging, slightly inclined towards a reservoir for the reception of such portions of their contents as may run over the sides. The cooling apartment should be airy, dry, and clean, and kept at as low a temperature as possible, in order to favor the rapid solidification of the gelatin, which generally takes place in 12 to 18 hours. After this, they are raised to the upper story, which is well ventilated with numerous slatted windows, and inverted upon a table with a smooth top well netted, so as to prevent the adherence of the emptied gelatinous cake to its surface. To detach it from the sides of the box, the moistened blade of a large knife is generally used. The mass is now first divided by a brass wire

stretched over a frame, like a bow-saw, into horizontal layers. The size of these layers is regulated by guides, which are placed at distances corresponding with the desired thickness of the cake of glue. The layers thus formed are dexterously placed upon net-work frames, which are arranged in the drying-room in piles at a distance of 3 or 4 inches from each other, so as to afford a free access of air. To hasten the drying, the plates of glue should be turned three or four times daily.

The drying is one of the most precarious steps of the process. The temperature of the atmosphere during the first several days of the desiccation has an important influence: for if it is too warm, the glue softens and runs through the meshes of the net, or adheres so firmly to the cords as to require maceration in boiling water for its separation. If the weather is too cold, the freezing of the water cracks the cakes, and renders it necessary to remelt them. A thunder-storm causes the glue to *turn* on the nets, even after it has been 2 or 3 days exposed; and a slight fog, by a condensation of the damp, so moulds the surface of the glue that it is sometimes requisite to remelt it; and a wind too dry or too hot may cause a so rapid desiccation as to prevent a proper contraction without cracks or fissures. In this case the best plan is to close the flaps of the windows.

The best means of preventing these inconveniences is to conduct the operation only in favorable seasons, the spring and fall of the year, when the temperature is more uniform and moderate.

After the glue is dried upon the nets, it is frequently necessary to lessen its flexibility by a further drying in a stove-room.

The plan of manufacture pursued in all the extensive glue factories of this country is somewhat different from the foreign method. Instead of the direct application of fire to metallic boilers, the materials are dissolved in slightly conical wooden vats, heated by the introduction of steam through a wrought-iron worm reposing upon the bottom. The whole arrangement is not unlike that used in the manufacture of alimentary gelatin. The cleansed materials are thrown into the vats, covered

with water, and then treated with a current of steam, until the solution is thick enough to be drawn off through the exit cock near the base of the vessel. This first running makes glue of quality No. 1. A repetition of this treatment with a fresh quantity of water, furnishes glue No. 2; which, when the materials are of ordinary purity, form the only two grades that are procured by boiling with steam.

Bone Glue. Gelatin can be extracted from bones in two ways: 1st, by digestion with water in steam-tight vessels; and 2d, by treatment with dilute hydrochloric acid, which dissolves out the calcareous salts and leaves the cellular tissue untouched. The first method, as before said, impairs the tenacity and adhesiveness of the gelatin, and consequently the latter plan is that solely used for the manufacture of bone glue.

Bones consist approximately of 40 pr. ct. of animal matter, and 60 pr. ct. of phosphate and carbonate of lime, of which the phosphate forms four-fifths. The acid dissolves the carbonate with disengagement of carbonic acid, and, by abstracting a portion of its base, transforms the insoluble phosphate into a soluble bi-salt; the chloride of calcium, which is also formed during the reaction, remains in solution with the other salts.

Practically, all bones are not equally good for yielding gelatin; some are so compact as to yield too slowly to the action of the acid, and others again do not give enough gelatin to pay the cost of the operation. Those bones called *fat bones* are unfit for this fabrication. Those most applicable are—

1st. *The cornuons of the ox or cow.* These are the bones occupying the interior of the horns. They yield more gelatin and of a better quality than any others, and moreover, by their porosity are more readily acted upon by the acid.

2d. *Skulls.* The skeletons of the heads of oxen and horses, being very thin, are readily attacked by the acids, and furnish a glue of handsome appearance. Before use they should be freed of the teeth which remain in the jaw, otherwise there will be a useless waste of a portion of the acid.

3d. *Button scraps.* These are the scraps of the thin plates from which the buttons have been cut. They give a very white glue of good quality, and their shape affords facility for extracting it.

4th. *Sheep skulls.* These bones also yield a very white glue, but of inferior quality and in less proportion than the preceding; and as their gelatinous product has a tendency to become milky, they are seldom used when better material can be procured.

Generally speaking, the bones are not subjected to any preliminary treatment, but it would be advantageous to give them a good soaking in clean waters. The bones being thus cleansed and freed of all foreign matters, will be more readily acted upon by the acid. It is rarely necessary to crush them, and as most of their grease is generally separated by those who make it a business, no operation is requisite to remove the slight portion that may remain.

To soften them, the bones are placed in

large wooden casks, or in square lead-lined vats of about two cubic metres' capacity, and completely immersed in hydrochloric acid (23° B.) diluted with four times its weight of water. The macerating vessels should be in a covered apartment and free from the sun, because at a high temperature the animal matter itself will be attacked.

A week's maceration completes the softening of the bones, which then must be removed by a cullendered leaden dip, and transferred to the edulcorating vats, where they are freed of acid and saline matters by repeated washings with water.

As the acid bath still retains some of its solvent power, it should be treated with a second quantity of bones equal to the first; these, after a day or two, having completely exhausted the acid, are then removed with the cullender and transferred to a fresh bath, where they remain, as the first, seven or eight days. The operation can thus be consecutively continued throughout the season.

The mode of operating would be more methodical by more frequent transfers of the bones from the baths. It is important too that the macerated bones should be carefully washed. This is generally done by exposing them to a current of water; and some manufacturers, to saturate any remaining traces of acid, subsequently dip them into a lime-water bath.

The residual acid-waters are an excellent material for the manufacture of phosphorus; and when saturated by ammoniacal waters and evaporated, form a valuable manure.

The softened bones, after having been thoroughly washed and dipped in lime-water, are freely exposed upon clean surfaces until perfectly dry. This desiccation is not only necessary for the storing of the bones, but is also indispensable to the good quality of the glue.

To convert these dried cellular tissues into glue, they are next digested with boiling water. When this operation is conducted in a copper, iron, or any metallic vessel, it is necessary, in order that the products may not be discolored, that the heat shall not exceed 212°. To provide against the contingency of scorching, and consequent injury to the materials, some manufacturers use a double kettle, the outer one of which being heated directly by the fire, serves, with the water which it contains, as a heating bath for the inner kettle containing the glue materials. A more recent and advantageous plan is to use wooden vats, or else lead-lined casks, which are heated by steam introduced through a worm resting upon the bottom and hugging closely to the sides.

Only so much water is used as is requisite to make the gelatinous solution without recourse to evaporation; and this latter, as soon as finished, is left for some time to settle and then drawn off into the cooling boxes. It should be passed through a sieve previous to passing into the boxes, so as to separate the insoluble impurities.

Sometimes the gelatinous solution is drawn off whilst boiling, into a second caldron enveloped with some material nonconductive of heat. After remaining therein for some hours

it settles and clarifies, and is then ready to be run into the boxes. After having perfectly congealed, it is taken out in masses of 8 inches length, 3 in. breadth, and 6 in. thickness, which are again subsequently divided into very thin layers previous to being transferred to the drying frames. For this purpose there is a simple and ingenious contrivance. In England they use a brass box, with a movable bottom, which can be raised or lowered at will to any desired extent, by means of a micrometric screw. The mass of gelatin to be divided being placed in this box, the bottom is then raised until the top of the glue extends beyond the ledges of the box to a height equalling the intended thickness of the plates of glue; then, with a brass wire stretched across the sides of a box-like frame, the protruding portion is sliced off, and thus is obtained the first cake of glue. The bottom being further elevated to the required height, a second cut is similarly made; and so on consecutively until the whole mass has been sliced. The lower slice, which retains the impurities which have settled during the cooling of the glue, should be thrown aside to be remelted and cleansed.

The qualities of glue. Well-made glue of good quality is bright and transparent, breaks with a conchoidal fracture, softens and swells in cold water without dissolving. To possess the greatest tenacity and unalterability by moisture, it must be made by the method first given, of treating the materials by consecutive solutions. The glues obtained with only one water are inferior, and more or less soluble in cold water.

Schattenmann, in a letter to Dumas, makes the following useful remarks in relation to the comparative values of different glues:

"I found by experiment that green glue, which is obtained by dissolving glutinous matters, dried much less easily than the jelly of glue which had been already dried and remelted; and that dried glue, soaked in cold water, imbibes, according to the different sorts and qualities, a greater or less amount of water; and that its body and cohesive force, as tested by this process, is in proportion to its real value.

"From these facts I concluded that the green glue derived from the fusion of the glutinous matters contains water of composition more intimately combined with the glue than the water arising from the remelting of dry glue, which is only in a state of admixture, and is disengaged and evaporates much more easily than the water of composition; that indeed the dry glue contains a certain quantity of water of composition, which diminishes by the frequent remeltings and desiccations to which the glue is submitted. I have from this drawn the conclusion that the manufacture of glue in thin leaves, susceptible of a more complete desiccation, is preferable to that in thick leaves, like the glues of Givet and Boulogne.

"I have recently made a series of new experiments, to ascertain the value of the dry glue from the quantity of water it imbibes in the cold, and the changes it undergoes by remelting, or by more complete desiccation. The

result of these experiments seems to me to be of great practical importance; for, if it be true that a dry glue of the same appearance may vary considerably as to strength or body, we must necessarily admit that the determination of the amount of dry glue should be abandoned, and in its place should be substituted that of the jelly obtained by the immersion of the dry glue in cold water at a temperature of 60° to 62° for 24 hours, because this jelly is the true expression of the quantity of the glue, and that the jelly thus obtained indicates by its greater or less consistence the quality of the glue.

"The bone glue, or gelatin, is evidently the best of all the strong glues, as much by its strength as by the consistence of its jelly.

"Our manufacture of this glue is so regulated as only to obtain thin leaves perfectly dried of two kinds of glue,—1st, the fine white bone glue; 2d, the fine blond bone glue.

"Our fine white bone glue, by its immersion in cold water during 24 hours, imbibes as a mean 12 times its weight of water; that is to say, that a leaf of 3 grms. gives 39 grms. of a firm and elastic jelly of very remarkable consistence.

"The fine blonde bone glue, treated in the same manner, absorbs as a mean 9 times its weight of water, and gives a jelly evidently less firm than the white bone glue.

"The common strong glue of Alsatia or of Germany, made with the offals from domestic animals, treated in the above manner, only imbibes as a mean 5 times its weight of water, and gives a very soft brown jelly, without elasticity and without consistence, and which falls to pieces by handling. This jelly, which is evidently of very inferior value and quality, is not to be compared with the jelly of our fine blonde bone glue, and still less with that of our white bone glue.

"The Boulogne glue made, like that of Givet, with the parings of skins of wild animals, and subjected to the same treatment after 24 hours of immersion, imbibes but 3½ times its weight of water; but after six times 24 hours it imbibes 7¼ times its weight of water. Its jelly is tolerably firm, and appears to be of good quality.

"The bone glue, remelted and dried afresh, soaked for 24 hours, absorbs as a mean a third more water than the quantity imbibed by the dry glue obtained from bones.

"Our remelted bone glues imbibe therefore as a mean—

"The fine white bone glue, 16 times its weight of water.

"The fine blonde bone glue, 12 times its weight of water.

"The jelly obtained from these glues possesses less firmness and consistence than that of the same glues obtained direct from bones.

"The loss or diminution resulting from the remelting of our dry bone glues is about 10 pr. ct., and thus it is not in exact relation with the superior capacity which the remelted glue possesses of imbibing a greater quantity of water.

"I attribute the diminution which the dry glue undergoes by remelting, partly to the losses inseparable to this operation, and partly to a more thorough expulsion of the water of

composition; and I find the proof of it in the superior capacity of the remelted glue for imbibing a greater quantity of water, and in this, that the well-dried glues, and especially those which have been remelted, are less hygrometrical than the badly manufactured glues, or those which are made from matters of bad quality which possess this property in a high degree.

"I think that the water of composition of the glue injures its quality, and that it paralyzes its cohesive force, and that thus its strength increases in proportion to its desiccation.

"From what precedes, I conclude that the surest practical means, and the most suitable for ascertaining the strength and quality of the glue, consists in soaking it for 24 hours in cold water, in order to convert it into jelly; that its quality must be appreciated from the consistence and firmness of this jelly, and its amount of cohesive matter from the quantity of water it imbibes.

"If the facts and principles which I have just exposed be true, as I am led to believe, it must be admitted that in practice the determining the value from the dry glue should be abandoned, because it is irrational and not precise; and that we should substitute for it that of the jelly obtained by the immersion of the dry glue in cold water for a certain time, of at least 24 hours.

"The result, moreover, is, that the glues of inferior quality, at a low price, instead of being economical, are, on the contrary, the cause of increased expense, and often injurious; for it is not seldom that the common strong glues, and especially the green glues obtained from the cuttings of skins, employed latterly in stiffening woollen goods, become putrid, and infect very valuable goods, especially when these are exposed to humid air or to an elevated temperature.

"We sell the fine white bone glue at 300 francs, and the fine blonde glue at 190 francs the 100 kilogrms. delivered at Paris, as we have mentioned in the notice sent with the sample of our products to the public exposition.

"Our fine blonde bone glue, soaked during 24 hours in cold water, imbibes 9 parts of water, and this gives 10 parts of firm jelly of excellent quality.

"The Alsatian or German glue, worth 130 francs the 100 kilogrms., treated in the same manner, only absorbs 5 times its weight of water, and thus it only gives 6 parts of soft jelly, which is brown and of bad quality. The result is that 100 kilogrms. of fine blonde bone glue, giving 1000 kilogrms. of jelly, and the same quantity of strong Alsatian glue, only giving 600 kilogrms. of jelly by their immersion in cold water for 24 hours at a temperature of from 60° to 62°; the jelly of the first glue costs but 19 francs, whilst that of the second amounts to 21½ francs the 100 kilogrms. Bone glue is an economy of 14 pr. ct. over the common strong glue, independent of the great superiority of the former in quality. Such is the result which the preference given to low-priced articles frequently leads to." *Ann. de Chim. et de Phys.*, Feb. 1845.

GENTIAN. The root of the *Gentiana lutea*. Its principal constituents are Oil of Gentian, Gentisin or Gentisic Acid, Gentianin, Pectin, and Sugar.

The oil, which is soluble in alcohol, is obtained by distilling the root with water.

Gentisic Acid. Obtained by the action of ether upon the inspissated alcoholic solution of the alcoholic extract of the root previously washed with water. Is pale yellow, crystallizes in needles, and forms yellow salts with the alkalies. When pure it is not bitter.

Pectin. To this component is due the occasional gelatinization of infusion of gentian under certain circumstances. The sugar ingredient causes the vinous fermentation, by which the alcoholic beverage used by the Swiss is made.

Gentianin. Syn. Gentianite. The bitter principle of the plant has not yet been obtained entirely isolated. Water dissolves out a bitter acid matter from the alcoholic extract of the root. This acid, when separated by a lead salt, leaves a solution which yields on evaporation a sweet and bitter extract, from which ether removes an aromatic fat, an odorous resin, and wax. The bitter matter has not been separated from the sugar. (*Pereira.*) The *Gentianin* of Dr. Baumert (*Chem. Gaz.*, v. 446) is not the bitter and medicinal principle of the root, but is a neutral body, which crystallizes in pale yellow tasteless needles, slightly soluble in water and most readily in boiling alcohol, and combines with acids and bases without parting with the elements of water. At 572° to 644° it disengages yellow vapors, which partially condense into yellow needles, but is mostly carbonized. Formula $C_{14}H_5O_5$.

GEODE. *Geol.* A small cavity in rock, or a detached hollow spherical stone, usually lined with crystals. Agate masses are apt to assume this form, internally coated with crystals of quartz.

GEOKRONITE. *Min.* Syn. Kilbrickenite(?). Cryst. Right Rhombic; also massive, with one imperfect cleavage; granular, earthy. $H. = 2 - 2.5$. $G. = 6.4 - 6.54$. Color and streak bluish gray; metallic; fracture uneven. It fuses readily, and gives the usual tests of arsenic, antimony, and lead. Form. $5 PbS, SbS_3$; or $PbS, SbS_3 + 4 PbS$, according to the analyses of Svanberg, Sauvage, and Kerndt. A part of the antimony is replaced by arsenic, except in that from Spain. *Kilbrickenite* is included in this species by Dana and Rammelsberg; although Apjohn's analysis gives 6 eq. of sulphuret of lead, which allies it to Brittle silver.

Local. Sala, Sweden; Meredo, Spain; Val di Castello, near Pietrosanto, Tuscany. See **ANTIMONIAL ORES.**

GEOGNOSY. } The science which treats
GEOLOGY. } of the structure of the earth and the history of its formation. It includes a portion of mineralogy as subordinate to it, in order to express the nature of rocks or mineral aggregates, and to identify formations from a similarity of mineral contents. It draws upon chemistry to illustrate the changes which formations undergo by the force of affinity. The principal minerals which it calls to its aid are

Quartz, Feldspars, Mica and Talc, Hornblende and Augite, Limestones.

Geological formations are either of igneous origin, mineral masses more or less perfectly fused by heat; of aqueous origin, deposited from water; or of an intermediate character, resulting from both the preceding causes combined, the sedimentary having been apparently subjected to heat, probably in the presence of water. The first and last are more or less crystalline; the sedimentary rarely so. The first embraces those without stratification; the third those which appear to have been sedimentary and still usually retain their stratified character. The last have been termed metamorphic rocks. Although these divisions are in general well marked, they graduate into each other so imperceptibly that it is often difficult to define their exact limits. Organic remains are abundantly distributed through the sedimentary formations; traces of organic forms are sometimes, but rarely, observed in the metamorphic series; and the true igneous rocks are wholly destitute of them. The igneous and some of the metamorphic rocks are often designated as Primary or Primitive, on the supposition of their having been first formed. The unaltered sedimentary rocks are either Secondary, the older rocks containing organic remains, or Tertiary, the latest formed previous to the human historic period.

I. Igneous rocks include, 1. *Granite*, composed of quartz, feldspar, and mica. If mica be wanting, it is termed *Granulite*; if both feldspar and mica be absent, it is called *Granular Quartz*; if mica predominate, it is *Mica slate*. 2. *Syenite*. When the mica is replaced by hornblende, it becomes a *Syenite*, or if partially replaced, a *Syenitic Granite*. When the rock is not crystalline, and consists largely of hornblende, it is termed *Aphanite* or *Hornblende Rock*. 3. *Protogine* or *Talcose Granite*, with talc replacing mica. When more magnesian and homogeneous, it is *Serpentine*, which graduates into *Diallage Rock*, composed mainly of feldspar and diallage. 4. *Trappean Rocks*. Frequently intrusive through sedimentary rocks, mainly consisting of feldspars and hornblende, very compact, and often slightly crystalline. 5. *Basalts*, composed of feldspars and augite, but usually so compact as to be destitute of crystalline structure. The variety *Dolerite* consists of labradorite and augite. 6. *Porphyry* appears to be a trap or basalt mainly composed of feldspar, with detached crystals of feldspar in a compact, feldspathic and quartzose matrix. Under it may be included *Linkstone* (Phonolite), compact, and lighter colored, and *Trachyte*, also compact, containing glassy feldspar. 7. *Lavas*, comprising *Obsidian*, or black volcanic glass, *Pumice*, a light-colored porous mass, and *Ashes*, a loose powder.

If detached crystals of feldspar be disseminated in any of the preceding, it is termed *Porphyritic*. Granites have usually a white, light gray or reddish color; syenites vary from these to nearly black, when hornblende predominates; talcose vary from light green to greenish black; trap, basalt and porphyry are usually very dark, gray, bluish, brownish, and black.

II. Metamorphic rocks generally run parallel to many of the igneous rocks; 1. *Gneiss*, and, 2. *Mica slate*, corresponding to granite; 3. *Hornblende slate* to syenite. 4. *Talcose slates* resemble gneiss and mica slate, with talc instead of mica. 5. *Chlorite slate* is allied to talcose slate, with chlorite instead of talc. 6. *Granular Limestone*, in which the sedimentary character is sometimes wholly obliterated, is highly crystalline, and constitutes most crystalline marbles. When abounding in carbonate of magnesia, it is termed *Dolomite*.

III. Sedimentary rocks. 1. *Clay*, usually ascribed to the decomposition of feldspars. 2. *Clay slate* is hardened clay, and when very compact, and without organic remains, is termed *Argillite*; when abounding in bitumen, *Bituminous shale* or slate. 3. *Sandstone*, composed of quartz sand, cemented by siliceous matter forming a very hard and tough rock, or by clay (argillaceous sandstone), when it is more friable, or by lime, forming a moderately hard rock. When the clay contains much oxide of iron, the rock forms a red or brown sandstone. Previous to its hardening or cementation, the formation is termed a *sand*. 4. *Conglomerate*, composed of fragments of rocks, less comminuted than sandstone. If the fragments be angular, it is termed a *Breccia*. *Millstone grit* is composed of quartz pebbles with a siliceous cement. Previous to cementation, a conglomerate is *gravel*. 5. *Limestone*, more rarely crystalline than granular limestone, and of various colors, although bluish gray is the predominating tint. When abounding in magnesia, it forms *Magnesian limestone*; in clay, an *Argillaceous limestone*. When the silica is in a finely divided state (probably hydrated), and it is slightly burned, it has the property of hardening under water, and is called *Hydraulic limestone*. Varieties are *Chalk*, *Oolite*, and *Marl*.

All the sedimentary rocks contain more or less organic remains. The sandstones and limestones abound more in marine shells or their casts. The slates more frequently contain vegetable remains. See **BASALT, CHALK, CLAY, GRANITE, &c.**

GERMAN SILVER. See **ARGENTAN** and **ALLOY.**

GERMINATION. That gradual development of an organized nucleus or germ which enlarges its structure, and by increasing its energies, enables the assimilation of matter necessary for its growth and sustenance. The chemical changes accompanying germination have not been minutely investigated.

GIALAPPONE. A variety of **JALAP** root examined by Cannobid. It contains

Resin, identical with jalap resin.	5-8
Gummy extractive.....	29-8
Starch	7-6
Veg. albumen	2-9
" Fibre	32-2
Water	16-0
Lime and Potassa salts	2-4

93-8

GIBBSITE. *Min.* Stalactitic and small mammillary; with a somewhat fibrous struc-

ture. $H. = 3 - 3.5$. $G. = 2.09 - 2.4$. Grayish or greenish white; translucent; with a white streak. It gives water in a closed tube, is infusible, and acts like pure alumina (!); soluble in acids. (Torrey.) Form. $Al_2O_3, PO_5 + 8 HO$. (Hermann.) Formerly regarded as hydrate of alumina. It occurs at Richmond and Lenox, Mass.; Union Vale, Dutchess Co., and in Orange Co., N. Y.

GIESECKITE. *Min.* Hexagonal; $H. = 2.5 - 3$. $G. = 2.78$. Grayish and dirty olive-green; greasy; subtranslucent, opaque; fracture, uneven, splintery. Its behavior resembles Pinite and Nephelin, to the latter of which Tamnau proposes to unite it. It occurs at Julianenhaab, Greenland.

GIGANTOLITE. *Min.* Hexagonal, cleavage parallel to 6-sided prism and end-plane. $H. = 3.5$. $G. = 2.86 - 2.878$. Greenish to dark steel-gray; between vitreous and waxy. Fuses readily to a greenish slag, with some intumescence; gives reaction of iron with the fluxes. Form. $RO, SiO_3 + Al_2O_3, SiO_3 + HO$, in which $RO =$ protoxides of manganese and iron, magnesia, potassa, and soda. It is allied to Fahlnite and Chlorophyllite. It occurs at Tammela in Finland.

GILBERTITE. *Min.* In white, silky, translucent plates; sectile. $H. = 2.75$. $G. = 2.648$. It appears from Lehunt's analysis to be $2 (Al_2O_3, SiO_3) + HO$. Found in lode of Stonagwyn, Cornwall.

GINGER. The root of the *Amomum zingiber* or *Zingiber officinale*. The two varieties are the black and white. Bucholtz's and Morri's analyses give as its composition: *Yellow volatile oil, acrid soft resin, resinous matter insoluble in ether and oils but soluble in alcohol, acidulous extractive insoluble in alcohol, gum, starch, fibre, ulmin (!), osmazome, bassorin, water, acetic acid, sulphur, and fixed salts.*

Volatile Oil. Lighter than water, and of odor similar to that of the root.

Ginger is mostly used as a spice, for domestic purposes, and occasionally in medicine. In company with other ingredients, its decoction forms the well-known beverage, root BEER.

GINSENG. See PANAX.

GIOBERTITE. See MAGNESITE.

GISMONDINE. See ZEAGONITE.

GLANCE. *Min.* The name of an order of minerals, adopted by some mineralogists, embracing those of a brilliant lustre; as Cobalt-glance, Iron-glance (specular iron).

GLANCE-COBALT. See COBALT-GLANCE.

GLASS. *Tech. Ger. Glas. Fr. Verre.* Glass consists essentially of silex and alkali heated to fusion, and presenting, after cooling, a transparent (rarely translucent) and hard body, without any tendency to crystalline structure. The history of its manufacture may be clearly traced from the present time through the times of the Romans and Phenicians to the Egyptians, some of whose productions remain to this day. It flourished in Tyre, in Alexandria, and lastly in Rome, and after being depressed for some ages, again revived under the Venetians, who transmitted it to the rest of the nations of Europe. The art has improved slowly during the last two centuries,

and has only within a few years begun to feel the influence of chemical science.

I. Composition and Properties. Glass consists of silex and alkali or alkaline earth, sometimes with other substances, chiefly metallic oxides, designed to modify its external characters of hardness, fusibility, brilliancy, color, and transparency.

1. Kinds of glass. The alkaline matter is usually introduced into it in the form of carbonate, sometimes as other salts, which are then decomposed.

Silex and alkali are in every kind of glass, but whether the alkali be potassa or soda determines the variety. Many kinds contain lime, and a few oxide of lead. Alumina and oxide of iron are constituents of one kind, and are contained as accidental impurities in nearly all the others.

The kinds of glass are—

1. Soluble, a silicate of potassa or soda, or of both.

2. Bohemian, a silicate of potassa and lime.

3. Crown or spread, a silicate of soda and lime.

4. Plate, silicate of soda and lime, cast into plates.

5. Bottle, silicate of potassa (or soda), lime, alumina, and oxide of iron.

6. Crystal, silicate of potassa and oxide of lead.

7. Flint, the same, with more lead.

8. Strass or paste, the same, with still more lead.

9. Enamel and colored glass, any of the preceding, except 1 and 5, colored by metallic oxides.

2. Materials. **1.** Silex, as white sand for the finer kinds, river sand for coarser glass, powdered quartz, calcined and ground flints. The last are now rarely used. The white sand in New Jersey is well adapted to glass-making. A superior quality of silex is found in Missouri, near St. Genevieve, consisting of a white sandstone, which appears to be destitute of cement, and crumbles to a fine sand. Sand frequently requires to be calcined, sifted, and washed, to remove organic and argillaceous matter. **2.** Potassa is used as purified pearl-ash (carbonate of potassa), soda as fine ash (carbonate of soda), for plate and the finer kinds of glass; common potash and crude soda for inferior qualities; sulphates of potassa and soda, and common salt, are used for the commonest glass. **3.** Lime, either as quicklime, air-slacked, or as carbonate (marble, chalk). **4.** Oxide of lead, as litharge or red-lead, rarely as carbonate or sulphate. **5.** To purify glass, nitre, binocide of manganese, and arsenious acid, are employed.

3. Chemical Relations. Silex, although infusible at any furnace heat, is brought into a melted and liquid state at high temperatures by the addition of various quantities of alkali (potassa, soda, lime) or of oxides of lead, iron or manganese. The definite composition of many crystallized, artificial and natural compounds of silex with various bases, pointing out its acid character, it is called silicic acid, and its compounds silicates. Silicic acid combines feebly with a strong solution of potassa

by digestion, but when exposed to heat, they readily unite to a melted mass; and if the potassa were carbonated, silicic acid expels the carbonic. Silica (silicic acid) combines in many proportions with alkali, some of which are doubtless definite crystallizable compounds, and the others are solutions by heat of the ingredient in excess in the definite compound. But these compounds and mixtures appear to be perfectly homogeneous and amorphous. Three pts. carbonate of potassa or soda form a very fluid mass with 1 pt. silica at a low furnace temperature, but a very small quantity of alkali is requisite to produce the same effect at a high heat. The compounds of potassa, from KO , SiO_3 to KO , 4 SiO_3 , are transparent and somewhat blebby; KO , 6 SiO_3 (85.7 pr. ct. silica) is transparent and very blebby; KO , 10 SiO_3 (91 pr. ct. silica) is still transparent, but very porous. The silicates of soda from NaO , SiO_3 to NaO , 4 SiO_3 are transparent and compact; those of NaO , 6 SiO_3 to NaO , 8 SiO_3 (90 to 92.4 pr. ct. silica) are transparent, but very porous; NaO , 10 SiO_3 forms a white enamel. For equal weights, the silicates of soda are more fusible than those of potassa. The alkaline silicates never assume a stony appearance, a crystalline or even lamellar structure, when cooled rapidly or slowly.

The silicates of lime are much less fusible or scarcely fusible. CaO , SiO_3 (62 pr. ct. silica) fuses with difficulty and imperfectly; with less or more silica the fusion is still more imperfect. Silicate of alumina is wholly infusible at furnace heats in any proportion. Several silicates of protoxide of manganese are fusible, those being most fusible between 3 MnO , SiO_3 and 3 MnO , 2 SiO_3 (containing 33.8 and 46.6 pr. ct. silica). Protosilicate of iron is much more fusible than that of manganese; even 6 FeO , SiO_3 (18 pr. ct. silica) fuses into a black scoria; FeO , 2 SiO_3 is still perfectly fusible, but the most fusible is 3 FeO , SiO_3 (31 pr. ct. silica). The silicates of magnetic oxide are somewhat less fusible than those of the protoxide; those of the peroxide of iron are infusible. The silicates of lead are most easily and most perfectly fusible, from 6 PbO , SiO_3 to PbO , 3 SiO_3 (12 to 18 pr. ct. silica).

Compound silicates are much more readily and perfectly fusible than the simple silicates. Hence, although silicate of lime is so difficultly fusible, it becomes readily so by admixture with alkaline silicates, and even the two nearly infusible silicates of lime and alumina will fuse perfectly in several proportions. Moreover, according to Berthier, the power of fusion seems to increase with the number of mixed silicates. It is on this ground in part that the advantage of mingling alkaline silicates with others depends in making glass. There appears also to be a more stable compound formed, one less easily acted upon by chemical agents; and this is probably the chief reason why bottle glass, the most mixed kind, although less fusible from the admixture of iron and alumina, resists chemical action most powerfully. The resistance of mixed silicates to the action of moisture is clearly shown by experi-

ments made on two kinds of glass, one composed of 1 pt. silica and 1 pt. potassa, the other of 1 pt. silica, 1 pt. potassa, and 1 pt. lime. While the former was deficient in brilliancy and solidity, and attracted moisture from the air so as to form a saturated solution of carbonate of potassa, the second was inalterable in the air, although it contained twice as much alkaline matter. The mixed silicates are therefore better for glass, by reason of their insolubility. There are other advantages presented by these mixtures. The silicates of lime, alumina, and oxide of iron, are usually crystalline, but mixed with alkaline silicates, are homogeneous, compact and amorphous. Again, the silicates of the alkalis and of lead are transparent, the others are translucent or nearly opaque; and although by fusing translucent silicates together, the mixture is more translucent, yet transparency is only attained by mingling alkaline and other silicates together. There are three classes of silicates employed in the manufacture of glass. The silicated alkalis are transparent, amorphous, soluble; silicate of lead is transparent, amorphous, insoluble; silicates of lime, iron, &c. are translucent, crystalline, insoluble. By combining two or more of these classes we obtain glass, transparent, amorphous, insoluble.

When carbonate of potassa, soda, or lime, are employed to make glass, the silicic acid expels the carbonic and unites with its base. The sulphates of soda and potassa are sometimes used to replace carbonated alkali wholly or in part. If charcoal be added at the same time, either the sulphuric acid is wholly reduced and sulphur expelled, or more probably a partial reduction takes place, and the escape of gas facilitates the escape of the remaining sulphuric acid. Without charcoal, an excess of lime or chalk is added, which forms sulphate of lime and falls to the bottom of the glass-pot, or where chalk is used, the escaping carbonic acid carries off a portion of sulphuric; for experience has shown that carbonate is better than caustic lime. An excess of charcoal imparts a yellow, brown, or greenish tint to glass. Common salt (chloride of sodium) is also introduced into glass, but it is not decomposed into alkali and muriatic acid, its chief action consisting in its volatility, whereby in rising through the melted mass it clears the glass, and forming a layer at the top, volatilizes if time be allowed. The chloride of potassium is more volatile than common salt, if the latter be added to a glass containing potassa, soda and chloride of potassium are generated, the former uniting with silica, and the latter rising to the top. By its greater volatility, chloride of potassium clears glass more perfectly than common salt.

As the materials employed in glass-making always contain a small quantity of oxide of iron, which imparts a greenish tint to it if in the state of protoxide, or faintly yellowish if peroxide, this inconvenience is obviated by adding a little peroxide of manganese, whereby the iron is peroxidized, and the manganese reduced partly to protoxide and partly to sesquioxide. The protoxide forms a colorless silicate, but the sesquioxide added to glass in

moderate quantity produces a violet color, which neutralizes the yellow color arising from peroxide of iron. A still better neutralization of color is produced by using a little oxide of cobalt, which gives alone a blue bordering on violet. To effect the same change of protoxide of iron into the less coloring peroxide, saltpeter and arsenious acid are used, the former of which, after losing oxygen, unites with silica; the latter, after giving off its oxygen, is dissipated in vapor as metallic arsenic. These oxidizing agents also destroy an excess of carbonaceous matter. If too much manganese be employed, the glass assumes a violet tint, which is obviated by thrusting in a wooden rod, which reduces the sesqui to the protoxide.

An excess of alkali is often used in order to obtain a more fusible glass, but such glass is more readily acted upon by acids, and even water boiled in it will readily convert red litmus to blue by its content of alkali. If pure water be boiled for some time in glass, it will almost always abstract a portion of alkali, without necessarily indicating an inferior quality of glass. The best test of its quality in this respect is to boil a little strong muriatic or sulphuric acid in it, and if the surface remain smooth and transparent the glass is good. Caustic fixed alkali attacks glass by dissolving silica. Fluohydric acid decomposes glass readily.

4. *Physical Characters.—Relations to heat.* All glass is fusible, but the temperatures for different kinds are different. Oxide of lead or a larger amount of alkaline silicate imparts more ready fusibility; and a similar effect is produced by borax. Bottle glass, containing oxide of iron and alumina, and less alkali, is more difficult of fusion than other kinds. When melted glass is cooled, it is perfectly flexible and plastic through a wide range of temperature before it becomes cooled to rigidity. The softer kinds, especially flint or borax glass, when heated, begin to be plastic below a red heat; the others, at higher temperatures; and the plasticity of all increases up to perfect fusion. When in the plastic state, two pieces will unite together as firmly as if they were melted together. Some glasses are more mobile than others when in fusion. When glass is much softened by heat it may be readily drawn out into rods or tubes, or, if passed around a revolving wheel, into minute flexible threads (glass hair). These relations of glass to heat are the principal properties on which depends the forming of glass into the numberless shapes demanded by the wants of civilized life. From its perfect mobility when fused, it may be cast into large sheets (plate-glass); from its plasticity below fusion, it may be moulded into any form by a few simple instruments, or by a mould of given form; from the firm union of two plastic pieces, very complex forms are attainable.

Glass conducts heat so imperfectly, that the end of a rod heated to whiteness may be held with safety by the hand within an inch or two of the heated end. But while this property is available for some uses, it is an inconvenience in other respects, which demands a remedy.

When a tumbler or other vessel of thick glass is cooled in the air (Bologna vial), if it do not fly to pieces on cooling, it will readily do so by dropping in a grain of sand or minute angular piece of flint, while it may be struck a smart blow with a wooden mallet or other smooth body. Prince Rupert's drops are pear-shaped pieces of glass with a long thin stem, made by dropping melted glass into water. The bulb may be struck without injury, but if the smallest particle of the stem be broken off, the whole drop flies into powder with explosive noise and violence. These effects are due to the bad conducting power of glass, combined with the cohesive force of its particles. Glass expands when heated; and contracts on cooling (see *EXPANSION*); but as its particles move more slowly in proportion as it approaches the cold rigid state, the rate of cooling must be very slow to allow the particles to come uniformly close together. If suddenly cooled by dropping melted glass into water, the outside suddenly assumes the rigid and more contracted form, while the interior is still soft and expanded, from the bad conducting power of the glass. When thoroughly cooled, the interior must still retain the expanded state, so contrary to its cohesive force at common temperatures, and when the cohesion of the outer layer is in the least disturbed, as by a scratch or slight fracture, the whole of the cohesive force exerts its power to fracture the whole mass. These facts point out the necessity of cooling more slowly than can take place in the air, and give rise to the process of *annealing*, whereby the glass vessel, as soon as made, and while still hot, is placed in one end of a long annealing oven, with a fire at this end, and gradually pushed to the farther and cold end of the oven. The particles of the interior and exterior have then time to arrange themselves uniformly according to their cohesive force at each point of temperature, until they become perfectly rigid.

When transparent glass is maintained for some time at a high heat, but below fusion, it becomes opaque or translucent, fibrous in structure, harder, less fusible, and a better conductor of heat and electricity; it is so much harder as to scratch glass, give sparks with steel, and will bear sudden changes of temperature like porcelain. It is commonly called devitrified glass, or Reaumur's porcelain; but its proper designation would be crystalline glass, as distinguished from ordinary amorphous glass. Although most glasses are subject to this change, yet it is most readily effected with common bottle or window glass. Although a portion of alkali is sublimed, yet the change is not dependent on the loss, nor on the presence of any accidental impurities. The alteration is wholly molecular, and consists in a rearrangement of the particles in a crystalline form, whereas glass itself is entirely amorphous. Similar changes in properties have been noticed among organic bodies in passing from the crystalline to the amorphous state. See *FUSION*. When crystalline glass is still more highly heated, it fuses, and then on cooling has the properties of amorphous glass, but requires a little higher heat for

fusion after each molecular change; which is due to loss of alkali.

Hardness and Elasticity. The different kinds of glass have different degrees of hardness, bottle glass being the hardest, from the quantity of oxide of iron and alumina, and the smaller amount of alkali. Lead glass is softer, and its softness in proportion to its content of oxide of lead. An excess of alkali imparts greater softness. The surface of glass appears to be harder than the interior. Quartz, other hard minerals, and a steel file, scratch glass readily, but the diamond, from its superior hardness, is employed to cut it. For this purpose the angles of the diamond should have a peculiar form, for any other angular fragment merely scratches glass. The curved facets of the diamond crystal present also curved edges, and while the point barely enters the glass, the curved edges or shoulders act like a wedge to split the glass in the direction of the cut. Glass is very elastic, as may be shown by any strip of window glass, but more strikingly by hollow balls suspended by strings. The ring or sound emitted by glass on being struck is dependent on its elasticity. A glass harmonicon consists of small strips of window glass of different sizes suspended on two parallel strings, and may be graduated to any scale. Goblets of various sizes are sometimes employed in a similar manner, and are made to vibrate by passing the moistened finger around their upper edges.

Defects in glass. Threads, tears, and opake points in glass are due to portions of the crucible or furnace dropping into the mass and not fusing perfectly. Having a different expansibility from glass, their presence is apt to cause the glass to break, at different temperatures, and sometimes without apparent cause. Air bubbles arise from the glass not having been kept very liquid for a sufficient length of time, and are often difficult to remedy after fusion. Chloride of sodium, and especially chloride of potassium, seem well adapted to clear glass of the air bubbles. Although striæ are often observed in every kind of glass, they are frequently and almost always found in flint glass, and are doubtless due to an imperfect commingling of the lighter alkaline silicates with the heavier silicates of lead. For ordinary articles the difference in density of the same piece is a matter of inferior moment, but is very important in lenses and glasses employed for optical instruments. To

obviate this defect various expedients have been tried with more or less success, but much yet remains to be done.

II. Details of Manufacture. 1. *Soluble glass.* Silicic acid, precipitated from its solutions, by acids, is soluble both in caustic potassa and soda. A crystallized soda-compound thus obtained has the composition $3 \text{ NaO}, 2 \text{ SiO}_3 + 27 \text{ aq.}$ ($= 56.5 \text{ pr. ct. aqua}$), and another crystalline body has the same formula but only 18 eq. water. Rose observed that 1 eq. silica would expel 3 eq. carbonic acid from carbonate of potassa, forming a silicate of potassa, $3 \text{ KO}, \text{SiO}_3$, which is soluble in water. Fuchs discovered these soluble combinations of silica and alkali, and termed them *water-glass*, or *soluble glass*. He mingled 10 pts. pearlash, 15 pts. quartz powder, and 1 pt. charcoal, and ignited it strongly in a refractory crucible for 6 hours. The mass is pulverized, added in small portions to boiling water until the whole is dissolved, and evaporated to a spec. grav. of 1.24 to 1.25, when the carbonic acid of the air ceases to decompose it. The liquid of 1.25 contains 28 pr. ct. silicate of potassa. By farther evaporation it is obtained in a solid form, resembling common glass, but much softer and more fusible. Döbereiner recommends 70 pts. carbonate of potassa, 54 pts. carbonate of soda, and 152 pts. quartz powder, which proportions are nearly $2 \text{ KO (NaO)}, 3 \text{ SiO}_3$. This glass is more fusible, and its solution more penetrating to wood. Soluble glass has been proposed and used as a paint for wood, textile fabrics, &c., in order to prevent their readily taking fire from sparks. For this purpose it is generally mingled with chalk, clay, bone-ash, &c., finely levigated. A thin solution should be first employed, in order to enter the pores of the wood, and followed by a solution with clay, &c., to protect the surface more perfectly. It may be highly recommended for shingle roofs, wooden bridges, and other structures, to render them more or less fire-proof.

2. *Bohemian glass.* The materials, consisting of silex, potash, and lime, are fritted in a *calcar* (colcar), or reverberatory oven, by being well heated, and thrown red-hot into the glass-pots or crucibles, where the fritted mass is melted. The objects of fritting are to expel moisture and carbonic acid, and produce a caking together, which facilitates fusion. The following table presents the proportions of materials employed.

					Average.
Silica	100	100	100	100	100
Pearlash (purified).....	60	40	50	53	50—60
Carbonate of lime.....	16	15	20	15	20—35
Saltpeter	..	..	2	..	0—2
Arsenious acid	..	..	..	1.6	$\frac{1}{4}$ — $1\frac{1}{2}$
Manganese	..	..	0.6	0.1	$\frac{1}{16}$ — $\frac{1}{2}$

The glass may contain some soda and less potash, and is fused in open pots, placed in a furnace of elliptical form. It is employed for making panes, tumblers, and various articles, which are characterized by their levity, as compared with flint and crystal glass, by its greater infusibility and resistance to chemical agents, as compared with a pure soda glass.

3. *Vial glass and spread glass* are similar in composition, containing silex, soda, lime, and sometimes potassa. The proportions of ingredients do not materially vary from those employed for Bohemian glass, but a smaller amount of soda is requisite than of potassa, because soda has a lower equivalent. (See the *Principles* above.) Less care is generally

had in regard to the quality of the materials than for finer kinds of glass; and hence this glass is almost always sensibly colored greenish by the protoxide of iron. For spread or common window glass, a considerable quantity of soda is used, in order to flux the materials rapidly, and the addition of salt is believed to clear the glass. (See *Materials* above.)

Where wood-ashes can be obtained cheaply, it is always substituted wholly or in part for soda, and then the glass approaches the Bohemian kind in composition. A pure soda glass melted and blown rapidly is apt to get stains on the surface, probably from the imperfect separation of chlorides; but if one-third or more of the alkali be potash, the stain is rarely observed. This is probably due to the greater volatility of chloride of potassium, which clears the glass more perfectly in a rapid melt. Vials, tumblers, druggists' ware, &c., of a light green color, are made from this glass. In making window panes, a lump of melted glass is taken out of the pot, blown and elongated into a pear, then blown and rolled into a cylinder, which is slit on one side longitudinally the whole length of the cylinder. It is then placed on the smooth hearth of the flattening kiln, with the slit sides uppermost, and when softened by heat, is opened, until it spreads out upon the hearth, a flattened sheet. The sheets were transferred then to the annealing kiln, but the two kilns are now so arranged, that after spreading, the sheet is not lifted from its bed. Chance's method consists in having two contiguous circular kilns, the hearths of which revolve. The hearth of the flattening kiln is composed of flat stones, and is highly heated near where the slit cylinder is introduced; it is then caused to revolve until the cylinder is opposite the working hole, where it is flattened. On being moved farther round, it is easily transferred to the revolving hearth of the annealing oven, where it is gradually cooled. It is evident that both these kilns might be united in one, and the heat of flattening employed for annealing.

4. *Crown glass.* The materials employed for crown glass are similar to those for the preceding kind, being silice, soda, and lime, but they are generally purer. One proportion is, 100 silica, 60 soda ash, 8 potash, 10 lime, 4 saltpeter, $\frac{1}{8}$ arsenious acid. Sulphate of soda is also used, with a little charcoal, instead of soda ash. Another proportion is, 100 sand, 16 soda ash, 40 chalk, with a little arsenic and manganese. The sand and chalk in powder are calcined, the former at a red, the latter at a lower heat, well sifted, and mixed with the other materials, also well dried, and then thrown into the melting pot. The object of calcination is chiefly to expel the water. The melting furnace is rectangular, containing from 4 to 6 pots, containing about half a ton of glass. The mingled materials are thrown in, the furnace quickly heated up to the melting point, and when the first charge is melted down, the next is thrown in, and so on until the pot is sufficiently filled. The temperature is lowered for a few hours, during which some of the foreign matters subside, and glass-gall

rises to the top, when, after raising the fire a little, it is skimmed off. A quantity of glass is taken up and rolled with blowing into a pear-shape, then heated at the "blowing furnace." It is again rolled and blown, and after a second softening at the blowing furnace, is expanded into a sphere. It is then heated at the mouth of another furnace, the "bottoming hole," being turned round by the blowing tube, which rests on a hook, when it assumes the form of a thick flattened disk, with a rising central cone, to which the tube is attached. Being transferred to the iron rod (*punto*) with a little glass on its end, the opposite end is broken off from the cone, and leaves the glass somewhat in the form of a crown. This crown is then held to the mouth of the flashing furnace, and turned round, first slowly, and then rapidly, during which it gradually collects together, when it suddenly flashes out into a flat circular disk of about 5 ft. diameter, with a thick mass in the centre, called the bull's-eye, where the punt is attached. The punt being detached, the plate is transferred to the annealing arch, where it is placed upright on its edge, and gradually cooled. The disks are then cut into panes.

5. *Plate glass.* This glass, usually cast into large plates for mirrors and large panes, is composed of silice, soda, and lime, nearly in the following proportions.

Silica.....	100	100
Carbonate of soda, pure..	33	33
Carbonate of lime.....	20	25
Manganese	..	$\frac{1}{3}$

All the material must be very pure. Pure soda crystals are prepared at St. Gobin, France, and dried; at Ravenshead, England, they employ pure soda ash. The lime is used as carbonate, dry slacked or caustic. All the materials are dried, sifted, and mingled together, and thrown into the melting pots, without previous fritting. The melting furnace contains 6 pots, capable of holding nearly a ton of glass, into which the materials are thrown, when the pots have been brought to bright redness, and suffered to remain 24 hours. It is then ladled into the squares (*cuvettes*), square-shaped pots in another furnace, where the metal, kept in a fused state for 12 hours, becomes refined by the escape of air bubbles and the settling of unfused matter. A square is then removed by a carriage to the casting table, made of cast-iron, and its contents poured out upon the table, proceeding from one end to the other, and followed by a roller to level the surface. The thickness of the plate is determined by rules on the sides of the table, over which the roller passes. The table being near the annealing arch, the stiffened, but not cold plate, is pushed into the annealing furnace, where it is gradually pushed from the hot to the colder end. Two plates are simultaneously ground, by cementing the lower one to a table and the upper smaller one into a frame, which moves over the lower by a peculiar eccentric motion, whereby true surfaces are obtained. The materials successively used between the plates are, sand; emery, Nos. 1, 2 and 3, for grinding.

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by machinery; emery, Nos. 4 to 8, for smoothing; and colcothar, for polishing, by hand.

6. *Bottle glass.* Is similar to vial or spread glass, but contains, in addition to silex, soda, and lime, oxide of iron and alumina. Formerly, the coarsest materials were employed, and the color was due to the accidental presence of oxide of iron. Latterly, however, better materials have been used, sand, soda ash, lime, clay, and smithy slack or iron ore, the latter to give color and impart hardness and resistance to acids. In this country, green sand is sometimes added to spread glass for beer-bottles, to which it gives a rich green color. Barytes is also used to a limited extent in France. The composition of bottle glass approaching to that of basalt and other igneous rocks (see **BASALT**), these rocks, either

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whole or disintegrated, have been employed, by mixture with sand, and sometimes alkali, to make bottles. Basalt is sometimes added to a spread glass to obtain the same result. The main difficulty attending the use of such rocks or other soils, lies in their want of uniform composition; but as good glass made from them has been proved to be of less specific gravity, more tough and resisting to chemical action, it would be highly desirable to substitute it wholly or in part for a glass composition.

7. *Lead glass* comprises three varieties, crystal, flint glass, and strass or paste, differing in the proportions of oxide of lead they contain. The following table shows the various proportions, from crystal with little lead to paste containing more oxide of lead than silica.

	Crystal.					Common Flint.			Optical.		Paste.		
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
Silica	100	100	100	100	100	100	100	100	100	100	100	100	100
Oxide of lead.....	10	30	42	45	58	66	70	80—85	100	100	133	154	160
Potash, purified ..	35	33	33	35	16	26	40	35—40	23	23	13	56	20
Saltpeter	..	10	15	..	..	7	3	2—3	..	1.3	..	..	20
Carbonate of lime.	13	..	..	..	8	..	..	.. Borax	7	1.8	..	6.3	..

No. 2 is a proportion recommended by Aikin, 8 proportions of Loysel, 9 optical flint glass of Bontemps, and 10 of Guinaud; 11 is a paste proposed by Lançon, 12 by Douault—Wieland, and 13 for ruby glass. Lead glass should be worked in closed pots, with a mouth opening outside the furnace, in order to prevent the access of carbonaceous matter, which would deoxidize the lead and blacken the glass. The furnace is generally circular, with a number of pots arranged on the inside. The dried and mingled materials are thrown into the white-hot melting pots, and when full of melted glass, the mouths are closed. Some heavy combinations of lead sink to the bottom, while the salts which will not incorporate with the glass, rise to the top as a scum, called *glass-gall*, *sandiver*; the greater part of this is skimmed off, the balance volatilizing. It is chiefly composed of chlorides. When the glass is cleared, the heat of the furnace is reduced, so that the very fluid metal is brought to a more plastic and workable state. The vessels, when finished, are put into the hot end of the annealing furnace on trays, which, as they become filled, are pushed along slowly until they reach the cold extremity of the oven. This furnace is sometimes 50 feet long.

Much more care is used in preparing the materials for optical glass and paste than for ordinary flint glass. For the two former, pure pulverized quartz is employed; and for paste, carbonate of potash from cream of tartar. To prepare a very pure glass, Kunckel and Neri recommend the melted glass to be quenched in water, pulverized and remelted. To imitate the diamond, as much pure oxide or carbonate of lead must be used as the paste will bear without assuming a yellow tint. It is very desirable to obtain a homogeneous flint glass for optical purposes, since strata of differing density have a tendency to form in it, rendering it unfit for fine lenses or prisms. Although

much has been done to attain such a glass, much more remains to be done.

III. *Colored glass.* Glass is most frequently tinged greenish or yellowish with oxide of iron contained in the sand or other materials employed, and requires the addition of oxide of manganese to remove the color. Too much manganese will impart a violet tint. In like manner, other metallic oxides are capable of imparting to glass various hues, which may be varied by combination or shaded by quantity. The coloring power of the different oxides varies, as may be seen by the proportions given below. *Yellow* is produced by charcoal, antimonite of potassa, silver, and oxide of uranium; *blue*, by oxide of cobalt, and probably by a mixture of oxides of copper and iron; *green*, by oxide of copper or of chrome (opake), or by antimonite of potassa, litharge, and cobalt; *red*, by gold, suboxide of copper (nearly opake), oxide of iron; *violet*, by manganese; *black*, by protoxide of uranium, iridium, platinum, and by a mixture of manganese, copper, iron, and cobalt; *white*, by oxide of tin, arsenic, and bone ash.

By combining one or more of these oxides, various shades and hues may be attained. The yellow glass of antimony may be shaded more into orange by the use of a little oxide of iron; the purple-red of gold passes into carmine by employing silver with gold; the blue of cobalt may be shaded into purple by a little gold, into green by antimony or other yellow colors. A rich grass-green is obtained from oxide of chrome with a little antimony and litharge; a brilliant emerald-green from a mixture of oxides of uranium and nickel; oxide of nickel alone yields a hyacinth-red. The ruby-red of gold requires much care in its preparation. 1. Dissolve 1 pt. gold in 18 pts. aqua regia, dilute it with 5 times its volume of water, and add $\frac{1}{2}$ of the solution to 512 pts. of the paste No. 13 in the above table

of lead glass, together with 48 pts. borax, 3 oxide of tin, and 3 oxide of antimony. Two pts. tin will be sufficient for heavier glass, and 4 pts. for smaller articles. The mixture is heated for 12 to 14 hours in an open crucible. 2. Dissolve 1 pt. pure gold in 12 pts. nitric acid, 12 pts. muriatic, and 1 pt. salamoniac, and add it to 1 pt. tin dissolved in 20 pts. nitric acid and 6 pts. muriatic, and diluted in a flask with 500 pts. water. This purple precipitate of Cassius is filtered, washed, and dried, and added in small quantity to the following mixture, 40 pts. quartz, 16 saltpeter, 8 borax, 1 arsenious acid, and 1 cream of tartar, and the whole is heated in a glass pot, with stirring until it has attained low redness, when it is covered and a higher heat given. When clear, the glass is cooled, pulverized, sifted, and mixed with a sifted glass composed of 128 pts. quartz, 64 saltpeter, 3 borax, and 3 arsenious acid. Thin glass made in this manner assumes a beautiful ruby tint by smoking it. The Bohemian ruby is prepared by fusing together 100 pts. quartz, 150 red lead, 30 fritted potash, 20 melted borax, 5 crude antimony, 5 manganese, and 5 pts. fulminating gold, ground up with oil of terpentine.

Glass is either colored throughout the mass, or several colors may be blown out together and retain their relative thickness when finished. This double glass (*Ger. Ueberfangglas, Fr. verre double*) is made by dipping the blowing tube first into one color and then into another. Thus, to make a red copper-glass vessel, with the coating inside, a small quantity of red glass is taken up, and when slightly cooled, it is dipped into colorless glass, of which a large quantity is taken up. The article is then blown, as a plate, and appears to be colored throughout. A colorless figure may be produced on a red ground, by cutting the figure through the thin layer of red to the colorless glass. The Germans have succeeded in thus combining different colors, more or less opaque, irregularly in one piece, presenting the appearance of agate and jasper, when cut.

Glass painting. It is convenient to distinguish glass colored as above from glass staining and painting. In the former the colors are made in the pot; in the latter they are brought upon the surface of a finished glass vessel, and burned in or upon the surface. The terms staining and painting are used confusedly, but the best distinction seems to be that, in staining, certain colors with their fluxes are brought on the surface of a pane of crown glass, and then fused in a muffle, whereby the transparent color diffuses itself uniformly over the whole surface. Painting is performed by applying the fluxed oxides with a brush, as in ordinary painting, and burning in, whereby the materials undergo imperfect fusion, and are translucent, rarely transparent.

For glass painting the following recipes may be given. The colors may be divided into those which are previously fused with a flux (stains), and those merely mixed with the flux (colors). *Red.* 1. Stain. 1 pt. oxide of iron is fused with 3 pts. of a flux (composed of 4 pts. sand, 4 pts. litharge, and 1 pt. borax), cast in cold water, and pulverized very fine.

2. Color. 1 pt. pure copperas, dried and heated, and ground with 2 to 3 pts. of the flux, gives from light red to violet; the flux is 6 pts. quartz, 4—5 litharge, 2—3 bismuth peari powder, mixed, heated to redness with stirring, then fused, cast into water, and pulverized.

3. Color. Equal parts ochre, fused litharge, antimony glass, sulphuret of copper and of silver, are ground with water, and applied without flux. 4. 1 pt. silver fused with 2 pts. crude antimony, powdered and mixed with as much oxide of iron, without flux. 5. 1 pt. purple precipitate of Cassius is mixed with 4 to 12 pts. flux (composed of 1 pt. quartz, $1\frac{1}{2}$ borax glass, $\frac{2}{3}$ red lead, fused, and ground). *Blue.* It is difficult to paint or stain with cobalt to obtain a transparent color. One plan is to fuse 1 pt. oxide of cobalt with 4 pts. borax glass for several hours, and to mix this stain with a flux of 1 pt. quartz and 1 pt. borax glass. The Saxon blue (*Königsblau*) may be used, mixed with various quantities of flux. Boracic acid is a convenient flux for cobalt. *Yellow.*

1. Stain. 1 pt. antimonic acid, 1 pt. carbonate of soda, and 2 pts. of a calcined mixture of equal pts. tin and lead, are fused with 24 pts. of a flux of 1 pt. quartz and 3 pts. red lead.

2. Mix 1 pt. oxide of silver with $\frac{1}{2}$ pt. antimony with a flux, fuse at a high heat, and pulverize; the flux is 2 pts. sand and 6 pts. litharge, fused and ground. 3. Color. Yellow oxide of uranium, 1 pt., is mixed with 3 pts. of flux (composed of 4 pts. red lead and 1 pt. quartz, fused and powdered). *Green.* 1. Stain. 1 pt. carbonate of copper is well mixed with 4 pts. powdered glass and 2 pts. red lead, kept fused until clear, then powdered. 2. 1 pt. oxide of copper, 10 pts. antimoniate of potassa, and 30 pts. flux (of 1 pt. quartz, 3 pts. red lead), fused. 3. 1 pt. borate of copper, 3 pts. glass, 1 pt. red lead. 4. Color. 3 pts. oxide of cobalt and 2 pts. tin, dissolved severally in nitric and muriatic acids, precipitated by carbonated alkali, washed, ignited, and mixed with 1 pt. quartz, 2 pts. litharge, and 1 pt. borax glass.

5. 1 pt. green oxide of chrome and 3 pts. flux (composed of 1 pt. quartz and 4 pts. red lead, fused and powdered). *Violet.* 1. Stain. 1 pt. manganese calcined with 1 pt. saltpeter, mixed with 6 pts. glass powder and 2 pts. red lead and fused. A little cobalt shades it bluish. 2. Color. 1 pt. chloride of silver is fused with 3 pts. quartz, 5 pts. burned borax, 1 pt. red lead, powdered and mixed with gold purple, according to the tint required. 3. Gold purple and cobalt glass gives a brilliant violet. *White.* 1 pt. bone ash or oxide of tin with 2 pts. lead glass. 2. *Black.* Equal pts. oxides of iron, copper, manganese, and cobalt, with 4 to 10 pts. flux of 1 pt. sand to 3 pts. red lead. By omitting cobalt, it forms a tolerable black; with more cobalt, a bluish black; with more manganese, a brownish black.

Opake glass. Oxide of tin, or bone ash, imparts an opacity to glass, more or less strong in proportion to the quantity of tin or ash, and an opalescence if in small quantity. Arsenic has been used, but is inferior. Colors may be given at the same time. Thus the bluish green of copper, or of copper and cobalt, produces a turquoise. A fine opaline green is given by

bone ash, with oxides of uranium and nickel. A simple and ingenious method followed in Bohemia in making alabaster glass, consists in melting ordinary glass, taking it out and quenching it in water. Another charge is introduced and melted, and the quenched glass thrown in. As soon as melted, the whole is worked off at the lowest temperature, and remains opaque or translucent. Glass colored by a sufficient quantity of oxide of tin to give it opacity, is termed enamel. Fluor-spar ground up may be painted on the surface of a glass pane, the portions to remain transparent scratched out, and the pane then heated in a muffle. It produces an effect similar to a ground surface.

Colors may be imparted superficially to glass by dusting them on an adhesive ground.

	Topaz.	Ruby.	Amethyst.	Garnet.	Sapphire.	Aqua Marine.	Emerald.
Colorless paste.....	1000	1000	1000	1000	1000	1000	1000
Antimony glass.....	40	..	..	500	..	7	..
Oxide of manganese ...	..	25	8	4	..	..	..
Gold purple.....	1	..	$\frac{1}{5}$	4	..	..	..
Oxide of cobalt	..	..	5	..	15	$\frac{2}{5}$	..
Oxide of copper.....	..	..	..	..	..	..	8
Oxide of chrome	..	..	..	..	..	..	$\frac{1}{5}$

GLAUBERITE. *Min.* Syn. Brogniartin. Cryst. Oblique Rhombic; cleavage perfect parallel to base. $H. = 2.5 - 3$. $G. = 2.75 - 2.85$. Pale yellow or gray; vitreous; brittle, with conchoidal fracture and white streak; taste, slightly saline.

Chem. Rel. In a tube it decrepitates violently; it fuses at low redness to a transparent glass, and on charcoal in the reducing flame, becomes hepatic, with or without soda; dissolves in borax with effervescence, and is absorbed by charcoal; dissolves similarly in mic. salt to a white glass; fuses with fluor-spar; decomposed by little water, leaving sulphate of lime; wholly soluble in a large quantity of water. Form. $NaO, SO_3 + CaO, SO_3$. It is formed artificially in concentrating salines by evaporation.

Local. In rock salt, at Villa Rubia, near Oceana, in New Castile; Vic, France; Aussee, Upper Austria.

GLAUBER'S SALT. *Min.* Syn. Sulphate of soda, Exanthalose. Cryst. Oblique Rhombic, in efflorescences. $H. = 1.5 - 2$. $G. = 1.48$. White; vitreous; transparent, opaque; taste saline, cooling. It fuses in its crystal-water, and on charcoal becomes hepatic; wholly soluble in water. Form. $NaO, SO_3 + 10 HO$. Its localities are numerous.

GLAUBER SALT. *Chem.* Crystallized sulphate of Soda.

GLAUCEUM LUTEUM. This plant is nearly allied to the *Chelidonium magus*. Its composition, according to Probst, is a characteristic acid alkaloid *Glaucin*, *Glaucic acid* identical with *Fumaric acid*, *Chelerythrin*, a brown humic acid, a brown basic substance, a bitter alkaloid *Glaucopierin*, a blue matter *Glaucotin*, and a yellow coloring substance answering to Xanthophyll.

Glaucin. Exists in the herbaceous parts of the young plant. It crystallizes from its solutions in hot water. The salts which it forms

By the same means an engraving may be transferred, by printing with the adhesive ground and dusting a color on the surface.

In the construction of compound pieces, such as windows, it is usual now to employ colored panes (from glass colored in the pot), and unite them by thin lead strips. Shading may be brought upon one side (by the brown color of oxide of iron, &c.). A green may be produced by a blue and yellow pane together, or a purple by red and blue. But where different colors are on the same pane, they must be wholly or partly painted.

Paste. The following recipes for colored strass or artificial gems, may serve to show their general composition. To 1000 pts. of paste No. 12 in the table of lead glass, are added the following oxides.

with the acids are white, neutral, and crystallizable.

Chelerythrin. Syn. Pyrrhopine. See **CHELDONIN**.

Glaucopierin. Crystallizes in white transparent plates. Is soluble in boiling water and alcohol, but very slightly so in ether. Its combinations with the acids are very bitter, and crystallize from their solutions by spontaneous evaporation.

GLAUCOMELANIC ACID. Formed by the action of air upon a strong solution of **BEZOARIC** acid in caustic potassa, and also the basic alkaline bezoarates generally. With bases it unites and forms bluish black salts, that of potassa at 212° losing all its water of crystallization without being at all altered in appearance. *Merklein and Wöhler, Ann. der Pharm., 1845.*

GLAUCOPICRIN. See **GLAUCEUM**.

GLAUKOLITE. *Min.* Massive, with traces of rhombic cleavage. $H. = 5$. $G. = 2.72 - 2.19$. Lavender blue, passing into green; vitreous; fracture splintery. It loses color by heat, and fuses with difficulty on the edges; borax and mic. salt dissolve it with difficulty. It is probably labradorite. It occurs near Lake Baikal, Siberia.

GLAUKOPHAN. *Min.* Long oblique 6-sided prisms. $H. = 5.5$. $G. = 1.08$. Light blue; translucent, opaque; brittle, with grayish blue streak; its powder is slightly attracted by the magnet; fuses readily and quietly to a dirty olive-green glass, and gives the reaction of iron with the fluxes. Form. $3 RO, 2 SiO_3 + 2 (Al_2O_3 + 2 SiO_3)$, in which $RO =$ protoxides of iron and manganese, magnesia, lime and soda. It occurs on the island Syra, with light-red garnet, actinolite, hornblende, and mica. *Hausmann and Schnedermann.*

GLAUKOSIDERITE. See **VIVIANITE**.

GLIADIN. See **GLUTEN**.

GLOBULIN. The substance extracted by

Berzelius from Bloon, and differs from albumen by its insolubility in saline solutions of a certain strength, and coagulability by heat into a granular mass. Together with hæmatosin it forms the chief portion of blood corpuscles. The two are difficultly separable, and hence globulin has not been obtained entirely free of hæmatin. Lecanu, in his analysis, couples the two together under the name of coloring matter. Simon considers globulin a peculiar form of CASEIN. It is of the protein group, and the formula for its compound with sulphuric acid is, according to Mulder, $15 \text{ Pr} + \text{S}$. The sulphate of globulin is of a dirty white color, and when incinerated leaves an ash more or less rich in oxide of iron. Its aqueous solution is brownish.

GLOTTALITE. *Min.* Cryst. Regular. H. = 3.5. G. = 2.18. White, vitreous, translucent; fuses with intumescence to a white enamel, behaving like the zeolites, which it evidently resembles. Form. $3 \text{ CaO}, 2 \text{ SiO}_3 + \text{Al}_2\text{O}_3, \text{SiO}_3 + 9 \text{ HO}$ (Berz. and V. Kobell), or $3 \text{ Ca O}, \text{SiO}_3 + \text{Al}_2\text{O}_3, 2 \text{ SiO}_3 + 9 \text{ HO}$ (J. C. B.) Found in the Clyde, Scotland.

GLUCIC ACID. See GRAPE SUGAR.

GLUCINUM. Syn. Glycium, Beryllium. The oxide of glucinum or glucina was discovered in 1798, by Vauquelin, the metal in 1828, by Wöhler and Bussy. Glucina is a rare earth, occurring in a few silicates, emerald, beryl, chrysoberyl, leucophane, euclase, phenakite, gadolinite, &c.

Glucinum. Dry chloride of glucinum is interstratified in a platinum crucible with flattened globules of potassium, a little less than sufficient to decompose the whole chloride; the cover is bound on with iron wire, and the whole heated over a Berzelius lamp. A violent action ensues, which heats the crucible to whiteness. The cover being removed, the whole is thrown into water, which dissolves the chloride of potassium and leaves metallic glucinum, as a dark gray powder with metallic streak, scarcely fusible. (Wöhler.) Becquerel obtained it in steel-gray scales by a galvanic battery.

It is soluble in dilute acids and caustic potassa with evolution of hydrogen, in oil of vitriol and nitric acid with evolution of sulphurous acid and nitric oxide respectively. It burns readily in the air to glucina.

Sym. G. Equiv. 7 (or 87.124 when O = 100, Berz.). According to Awdejew, glucina is composed of GO, in which case its equiv. would be 4.65 (or 58.04, O = 100). But Berzelius makes it probable that glucina is G_2O_3 , like alumina, whence its equiv. 7.

Glucina. Ger. Beryllerde, Süsserde. *Prep.* From beryl, which contains about 13 pr. ct. glucina. 1. By igniting 1 pt. in powder with 3 pts. caustic or carbonated alkali, dissolving in water, evaporating to dryness to render the silica insoluble, dissolving in muriatic acid water, precipitating by ammonia and washing, digesting the precipitated alumina and glucina with carbonate of ammonia, which dissolves glucina; filtering and boiling the solution, which precipitates carbonate of glucina; washing, drying and igniting gives pure glucina.

(Vauquelin and Berzelius.) 2. To separate alumina and glucina, precipitated by ammonia, dissolve in potassa, which leaves oxide of iron, supersaturate slightly with chlorohydric acid, precipitate again by ammonia, dissolve in sulphurous acid, and boil the clear solution, which precipitates basic sulphite of alumina and leaves sulphite of glucina in solution. Berthier.

Prop. A light, voluminous, white powder, adhering to the tongue, tasteless, insoluble in water, spec. grav. 2.967. Form. G_2O_3 . It is distinguished from alumina by its solubility in carbonate of ammonia, by not precipitating when its solution in sulphurous acid is boiled, by precipitating from a dilute boiling solution in potassa, by its not becoming blue when heated by the blowpipe with a solution of cobalt.

The hydrate is precipitated from a solution by caustic fixed alkali; that obtained from the chloride by ammonia in excess is $\text{G}_2\text{O}_3 + 4 \text{ HO}$. Schaffgotsch.

Sulphuret of Glucinum, obtained by heating the metal and sulphur together, is a gray mass, slowly soluble in water without evolving sulphohydric acid. Wöhler.

Phosphuret of Glucinum, made by heating the metal in vapor of phosphorus, is a gray powder.

The salts of glucinum are easily made by dissolving the hydrate in acids, but the affinities of the earth are less than those of the alkalis, and yttria, although by boiling it decomposes the ammoniacal salts. The salts are colorless with a colorless acid, generally soluble in water, redden litmus, and have a sweet and astringent taste. The caustic and carbonated alkalis precipitate it in the cold, carbonate of baryta by heat; phosphate and succinate of alkali produce white precipitates; when fluoride of potassium is added to a warm solution until a precipitate appears, a crystalline double salt separates on cooling; yellow prussiate of potash forms after some time a gelatinous mass.

1. *Haloid Salts.* *Chloride of Glucinum.* G_2Cl_3 . The dry salt is obtained by mingling glucina and lampblack, drying by a strong heat, and passing chlorine gas over it in a porcelain tube at a high heat, as in preparing chloride of ALUMINUM. It sublimes in white scales, very fusible, and soluble in water; by evaporation in the desiccator it crystallizes with 12 eq. water. The bromide and iodide, $\text{G}_2\text{Br}_3, \text{G}_2\text{I}_3$, are obtained by heating glucinum in vapor of bromine and iodine respectively, and are very fusible and volatile needles. The fluoride, G_2F_3 , obtained by solution of the earth in fluohydric acid, dries down to a transparent gummy mass. The fluoride of glucinum and potassium, $3 \text{ KF} + \text{G}_2\text{F}_3$, precipitates crystalline scales from the mingled solutions of the two salts. *Silicofluoride of glucinum*, $3 \text{ G}_2\text{F}_3 + 2 \text{ SiF}_3$, is very soluble, uncrystallizable.

2. *Oxysalts.* *Neutral sulphate of glucina*, formed by nearly neutralizing dilute sulphuric acid with carbonate of glucina, concentrating and allowing spontaneous evaporation, yields 8-hedra, of the form. $\text{G}_2\text{O}_3, 3 \text{ SO}_3 + 12 \text{ HO}$ (40.56 pr. ct. aq.), soluble in water, insoluble in alcohol, decomposed by a strong heat. By digest

ing the neutral salt with carbonate of glucina, until carbonic acid ceases to pass off, filtering, and diluting until precipitation ceases, filtering again, and evaporating, the $\frac{1}{2}$ sulphate is formed, $2\text{G}_2\text{O}_3, 3\text{SO}_3$; if evaporated without dilution, the $\frac{1}{3}$ sulphate is formed, $\text{G}_2\text{O}_3, \text{SO}_3$; if the preceding solution be diluted with water, the $\frac{1}{6}$ sulphate precipitates, $2\text{G}_2\text{O}_3, \text{SO}_3 + 3\text{HO}$; by mingling sulphate of potassa and of glucina, and evaporation in the desiccator, a double salt is formed $3(\text{KO}, \text{SO}_3) + \text{G}_2\text{O}_3, 3\text{SO}_3 + 6\text{HO}$; the *sulphite*, $\text{G}_2\text{O}_3, 3\text{SO}_2$, is soluble, and decomposed by boiling. The *nitrate*, $\text{G}_2\text{O}_3, 3\text{NO}_5$, crystallizes with difficulty, and is soluble in alcohol. The *phosphate*, $2\text{G}_2\text{O}_3, 3\text{PO}_5$, is a mucilaginous mass; the *phosphite*, $2\text{G}_2\text{O}_3, 3\text{PO}_3$, a white powder; the *hypophosphite*, $\text{G}_2\text{O}_3, 3\text{PO}$, a hard, vitreous mass. The *carbonate*, $\text{G}_2\text{O}_3, \text{CO}_2 + 5\text{HO}$, is a flocculent precipitate; that obtained by boiling its solution in carbonate of ammonia, is a light powder, characterized by its ready solution in carbonated alkali, especially in carbonate of ammonia; the *oxalate*, $\text{G}_2\text{O}_3, 3\text{C}_2\text{O}_3$, is gummy, soluble, and very sweet; the *rhodizionate* has a chocolate-brown color; the *croconate*, $\text{G}_2\text{O}_3, 3\text{C}_5\text{H}_4$, is yellow, crystallizable, soluble in alcohol and water.

For silicate of glucina, see PHENAKITE; for silicate of alumina and glucina, see BERYL and EUCLASE; for aluminates of glucina, see CHRYSOBERYL. Other oxysalts and the sulphosalts of glucinum, see under ARSENIC, SELENIUM, TELLURIUM, &c.

GLUCOSE. See STARCH.

GLUE. See GELATIN.

GLUE, MARINE. A composition, invented by Jeffery, of London, which is remarkable for its tenacious adhesiveness. It is completely insoluble in water, and, moreover, is not affected by the heat of the sun. It resists a traction of 20 to 25 kilogrammes per square centimetre, and so great is its power of resistance, that it is more easy to break the wood in a new place than at the juncture cemented by this glue.

This glue is a solution of 450 grammes of caoutchouc in 18 litres essential oil of tar, to which is added shellac.

The proportions. After ten days' maceration of the caoutchouc in the liquid, the mixture takes a thick creamy consistence, and at this time two parts of shellac to one of solution are added. The whole is then heated and poured out into plates. It is applied at about 250°.

GLUTEN. An ingredient of the fruit of the cereals. Mulder prepares it by kneading wheat flour, of which it forms from 20 to 25 pr. ct., with water. Soluble albumen, gum, sugar and starch being thus removed, the residue is treated with alcohol, precipitated by water, redissolved twice in alcohol, and again thrown down by water. When dried at 266° it has the formula $\text{C}_{200}\text{H}_{155}\text{N}_{25}\text{O}_{60}\text{S}$ or $5\text{Pr} + \text{S}$.

As usually obtained, merely by removing the starch with water, it is a complex compound, separable into three distinct substances, Glafadin, Glutin, and Fibrin.

It is adhesive, elastic, brittle when dry, and

hable to decomposition when moist; insoluble in water, but soluble in alkalies, acetic and dilute phosphoric acids. The precipitates produced in its dilute potassa solution by the two latter acids, redissolve in an excess of either.

Glafadin. Separated from the impure gluten by cold alcohol. Transparent and reddish when dry; softens and swells, but does not dissolve in water:—tartaric acid renders it apparently soluble, but tannin precipitates it from this solution. It is by this acid and the alcohol, says Francois, that it is held in solution in wines, and to its presence is due the turbidness occasioned in white wine when being converted into artificial champagne by a surcharge of carbonic acid.

Glutin. Extracted by boiling alcohol, and forms that part which does not precipitate from the cooled solution. Obtained by evaporation, it is soluble in alkalies and acids; of the latter, the hydrochloric giving a blue solution. Its acetic solution is precipitated by chloride of mercury and infusion of galls, but not by acetate of lead nor persulphate of iron. Though of the same ultimate composition as albumen and casein, it differs from them by its solubility in alcohol.

It is the gluten of flour that gives its property of being converted into BREAD. The vinous fermentation of its saccharine portion promoted by small additions of yeast, generates the carbonic acid which expands the gluten into vesicles, and thus causes the light spongy consistence of the baked loaf.

GLYCERYL. Syn. Glyceren. The hypothetic radical (C_6H_7) of Glycerin.

Glycerin. Scheele's "sweet principle of fats." The oxide of glyceryl is a yellowish sweet-tasting viscous liquid, existing as the organic base of certain organic acids (oleic, &c.) in the various FATS and fat OILS, and as phosphoglyceric acid in the yolk of egg. *Gobley.*

Preparation. It is obtained pure by saponifying olive oil or any one of the animal fats with litharge, and carefully replacing with boiling water such of the first added portions of that liquid as may escape by vaporization during the heating. The soap being made, the glycerin remains dissolved in the water, from which any lead must be separated by a stream of sulphuretted hydrogen gas. The decanted liquor, freed of the excess of this gas by boiling, and purified by filtration through washed bone black, gives, by careful concentration in a stove or vacuo, pure glycerin.

Properties. In an anhydrous state (glyceric ether) its formula would be $\text{C}_6\text{H}_7\text{O}_5$; but it is never found uncombined with water, and hence it is $\text{C}_6\text{H}_7\text{O}_5, \text{HO}$. Its spec. grav. varies from 1.25 to 1.27. Alcohol and water mix with it in all proportions. In ether it is insoluble. Its solvent power is almost equal to water, and extends to all the deliquescent salts, and even to oxide of lead and some of the metallic nitrates, chlorides, and sulphates. (*Pelouze.*) Solid potassa transforms it, by a gentle heat, into acetate and formate, with disengagement of hydrogen. (*Dumas and Stass.*) Nitric acid converts it into water, carbonic and oxalic acids. Chlorine generates a white flocculent precipitate, of an ethereal

odor and acid astringent taste, the formula of which is $C_{12}H_{11}Cl_3O_{10}$. This compound corresponds to a chloric ether. By substituting bromine for chlorine in the preceding reaction, an analogous ethereal compound is formed, of the same composition. Glycerin has no tendency to fermentation, but, according to Redtenbacher, when mixed with dilute ferment and exposed for some months at 70° to 85° , it yields metacetic acid. (*Millon's Annuaire*, 1847, p. 508.) It is decomposed when boiled with a solution of sulphate of copper; its compound with potassa is soluble in alcohol.

With sulphuric acid it forms *Sulpho-glyceric Acid* (*Bi-sulphate of the oxide of Glyceryl*, Liebig), $2 SO_3, C_6H_7O_5 + HO$, which readily decomposes, especially by heat, into glycerin and sulphuric acid.

The *Sulpho-glycerates* formed by neutralizing this acid with bases are double salts, and according to Pelouze, are analogous to the sulphovinate, like which, one eq. of water is lost to the free glycerin in these combinations. These compounds are very soluble and crystallizable, but readily decomposed by ebullition.

Phospho-glyceric Acid. Form. $PO_5, C_6H_7O_5$, (Pelouze.) Its salts are soluble in water, but insoluble in alcohol, those of lime and baryta being precipitated thereby from their aqueous solutions. The lime salt, however, is more soluble in cold than hot water, and readily drops from its solution in the latter at $212^\circ F$. The identity in composition of the benzoate of glycerin with *picrotoxin* (Liebig), strengthens the inference of Goble that this base exists in other combinations than with the fatty acids.

Glycerin is inflammable, and burns with a luminous flame. Among the products generated by its destructive distillation are *acrolein*, a new acid *acrylic*, resembling the acetic, sulphurous acid, and *acrole resin*.

Acrolein. It is best prepared by distilling glycerin with bisulphate of potassa in excess. The entire contents of the recipient, digested with oxide of lead until the absence of all acid reaction, by redistillation, yield pure acrolein, which when dried over perfectly neutral chloride of calcium, is freed of the water which passes over with it. (Redtenbacher.) To prevent the decomposition of the acrolein, the apparatus must be freed of air by carbonic acid.

Prop. When pure, it is transparent, colorless, highly refractive, and of an acrid irritating odor. Spec. grav. lighter than water, boils at 126° , dissolves readily in ether and in 40 pts. of water, imparting to the latter its odor and taste. By absorption of oxygen, especially in aqueous solution, it is transformed into white *disacrone* and acrylic acid, and even undergoes this change whilst hermetically closed in bottles. Chlorine and bromine form oily compounds with evolution of hydracids. It is carbonized by sulphuric acid with evolution of sulphurous acid. Nitric acid oxidizes it with slight attendant deflagration and disengagement of nitric oxide gas. Ammonia added to its ethereal solution, precipitates as crystalline carbonate. Potassa generates resinous products, and transforms the original smell into that of cinnamon. According to Redtenbacher, it is the hydrate of the oxide of *acryl* (a

new radical, C_6H_3), and its formula accordingly is $C_6H_3O + HO$.

Acrylic Acid. Form. $C_6H_3O_3, HO$. Produced by the oxidation of acrolein. It is so similar to acetic acid in odor and taste, that it is difficult to distinguish one from the other. It is a volatile liquid, and forms salts with the bases. The acrylate, and acetate of silver, correspond in appearance; the former is convertible into the latter by dissolving it in ammonia and saturating the solution with nitric acid. The *acrylate of soda* crystallizes in small transparent prisms, which effloresce upon exposure.

Hydrate of Acrylic Acid. An empyreumatic-smelling limpid liquid, resembling acetic acid. Solidifies below 32° , boils at $212 F$, and distills unaltered. *Acrylous acid* is intermediate between acrolein and acrylic acid, similarly as acetylous acid exists between aldehyde and acetic acid.

Disacrone. The tasteless, inodorous white powder ($C_{10}H_8O_4$) formed by the prolonged action of water upon acrolein; is insoluble in acids, alkalies, and other solvents; fused potassa dissolves it. The water from which *disacrone* is separated after its formation, as above, contains formic, acetic, and acrylic acids.

Disacrone Resin. A pulverulent white substance, formed sometimes under the same circumstances precisely as *disacrone*. It melts at 212° , is insoluble in water, but dissolves in ether, alkalies, and alcohol, from the latter of which it separates by careful evaporation in glittering scales. When dry, its formula is $C_{20}H_{13}O_3$.

Acrole Resin. The resinous product formed with evolution of cinnamon odor by the action of alkaline solutions upon acrolein.

The properties of glycerin and acrolein, and the oxidation of the latter to an acid, resembling the acetic, point out the relation of these bodies to an alcohol. But if we compare acrolein, $C_6H_4O_2$ ($C_6H_{n-2}O_2$) with any alcohol $C_nH_{n+2}O_2$, we observe the discrepancy at once. When acrolein is oxidized by nitric acid, acetic and formic acids are produced, by the addition of $2HO + O_2$; thus $C_6H_4O_2 + 2HO + O_2 = C_6H_6O_8 = C_4H_4O_4$ (acetic) + $C_2H_2O_4$ (formic). When oxidized slowly in close vessels, *disacrone*, together with formic, acetic, and acrylic acids are formed; and Berzelius observes that, if from 2 eq. acrolein, $C_{12}H_8O_4$, we abstract and oxidize C_2H_2 , acetic, formic, or *disacrylic acid* will result, while there remains *disacrone*, $C_{10}H_6O_4$. It appears highly probable from a consideration of all these reactions that acrolein is either a conjugate acetic acid, $C_{12}H_8O_4 = C_8H_4 + C_4H_4O_4$, or it is a conjugate formic aldehyde, $C_6H_4O_2 = C_4H_2 + C_2H_2O_2$. The latter is the more probable view, because acrolein has a neutral reaction, although formic aldehyde is unknown, unless it be in form-methylal. By partial oxidation it is converted into acrylic acid, which would be formic acid with the same conjugate $C_6H_4O_2 + O_2 = C_4H_2 + C_2H_2O_4$. By oxidation of acrylic acid (or a stronger oxidation of acrolein) formic and acetic acids result, the latter being formed from the conjugate by assuming $2HO$ and O_2 .

$C_2H_2 + 2 HO + O_2 = C_4H_4O_4$, acetic acid. The formation of disacron with one of these acids is also more readily explained and accords with Berzelius' remark. Moreover, the behaviour of acrolein to nitrate of silver is analogous to the behavior of aldehyde; the white precipitate is reduced, some metallic silver formed, and acrylate of silver dissolved. Berzelius suggested that the white precipitate is acrylite of silver, and that there is therefore an acrylous acid, of the composition $C_6H_4O_3$ or $C_6H_3O_2$, HO, or that it is hypacrylite of silver, the acid being $C_6H_4O_2$ or C_6H_3O , HO. The former is the more probable, and gives us a conjugate formylous acid, $C_4H_2 + C_2H_2O_3$. The latter is closely analogous to acetylous or aldehydic acid. Berzelius had already observed that acrolein bore the same relation to aldehyde, as acrylic to acetic acid, from a similar mode of oxidation, and that they appeared to have a corresponding intermediate oxidation. Alkali also forms with acrolein as with aldehyde, acrole resin. It appears then that acrolein is a conjugate methaldehyde; acrylous or formylous acid is a conjugate methacetylous acid; and acrylic is a conjugate methacetic acid. The formation of acrolein from glycerin will be readily understood by the distillation of the latter alone or with phosphoric acid; glycerin, $C_6H_8O_6$, loses 4 eq. water and becomes acrolein, $C_6H_8O_6 - H_4O_4 = C_6H_4O_2$. This result is probably due to a series of reactions, as follows: Glycerin by distillation yields methylic alcohol and a body of the composition of acetic acid: $C_6H_8O_6 = C_2H_4O_2 + C_4H_4O_4$. By an internal combustion during the distillation, the alcohol loses 2 eq. hydrogen, which, with 2 more of hydrogen and 4 of oxygen, pass off as water, leaving methaldehyde with its conjugate, C_4H_2 .

Berzelius considers that the basic constituent of fats is oxide of LIPYL (a new radical $= C_3H_2O$), and that like the base in the compound ethers (when it is set free from the fat acids), it enters into a new combination with the elements of water, and forms glycerin; but this change is not perfectly analogous to the conversion of the oxide of ethyl into alcohol, for 2 atoms of oxide of lipyl combine with the elements of 3 atoms of water to form one atom of glycerin $= C_6H_7O_5$, which then combines with one atom of water to form a hydrate. To these facts he attributed the difficulty of combining glycerin with the acids to form salts, or of obtaining oxide of lipyl with other than the fatty acids. More lately, however, Pelouze and Gelis have succeeded in forming *butyrin* artificially by the action of sulphuric acid upon a mixture of butyric acid and glycerin (now considered as belonging to the alcohol series); but the number of equivalents of water lost by the glycerin, entering into combination, was not determined by these chemists. Some researches by Redtenbacher (*Chem. Gaz.*, vol. iv. 292), later than those before referred to, have shown that glycerin yields by exposure for several months at 68° to 86° , with the presence of yeast, metacetic acid.

GLYCOCOLL. See GELATIN, Sugar.

GLYCYRRHIZA GLABRA. Licorice root

contains Glycyrrhizin, starch, asparagin, resinous oil, albumen, woody fibre, malic and phosphoric acids, lime, and magnesia.

The slight acidity of the root is due to the resinous oil.

Glycyrrhizin. Dr. Lade (*Liebig's Annalen*, 1846) has made some late investigations as to this substance. Obtained by evaporation from its alcoholic solution, it is a transparent, shining, brown mass, which yields a brownish yellow powder. Partially soluble in hot, and less so in cold water. The hot saturated aqueous solution solidifies on cooling to a brown transparent jelly. It is very sweet, and is readily dissolved by alcohol, but not by ether.

Continued digestion with dilute sulphuric acid produces no transformation into grape sugar, nor can it be fermented by means of yeast; hence it is one of the class of uncrystallizable sugars without tendency to fermentation. Lade's formula for glycyrrhizin is $C_{36}H_{22}O_{12} + 2 HO = C_{36}H_{24}O_{13}$, and differs from that previously given by Vogel, jun., $C_{16}H_{12}O_6$. By solution in nitric acid, oxidation ensues, and the addition of water precipitates a yellowish white caseous substance, which, dried over a water-bath, becomes a yellowish white, loose powder. This precipitate dissolves in alcohol and ether, but is separated by water, in which it is but sparingly soluble, though it imparts thereto a bitter taste and acid reaction. From alkaline solutions it is precipitated unaltered by acids. Its formula is $C_{36}H_{23}O_{17}$, and a minute portion of nitrogen. Its compound with lead is a beautiful lemon-yellow powder.

Glycyrrhizin combines with bases, and the formula for its lead salt is $PbO, HO + C_{36}H_{22}O_{12}$.

The common licorice paste found in commerce is the inspissated aqueous extract of the root, and this extract, when further purified by resolution and evaporation, and rolled into thin sticks which are glazed with a solution of gelatin, become the refined licorice of the shops.

GMELINITE. See CHABAZITE.

GNEISS. *Geol.* A rock composed of quartz, feldspar, and mica, in varying proportions, and included among the metamorphic rocks. It is durable building-stone, and its tendency to lamination, due either to its original deposition or the parallelism of the micaceous scales, makes it easily quarried, while its general softness adapts it well to trimming. When the mica is very abundant, it graduates into mica-slate, and forms a good material for the construction of some chemical furnaces. See GEOLOGY.

GOKUMITE. See IDOCRASE.

GOLD. *Min. Syn.* Native Gold; *Ger.* Gediogenes Gold. Cryst. Regular; combinations are the 6-8-12-24- 4×6 -hedra. Pl. VIII. figs. 1—6 and 8—10. It has been observed compounded like fig. 52, Pl. IX., but in the form of the 24-hedron, fig. 4. It is oftener found in imitative forms, filiform, reticulated, arborescent, and in laminæ, rolled grains, or larger masses. H. = 2.5 — 3. G. = 12 — 20. Color gold-yellow to very light yellow; metallic; opaque; ductile and malleable.

GOLD.

Chem. Rel. Almost all gold contains silver together with small quantities of iron, copper, &c. If it contain but little silver, it gives an opalescent glass with mic salt; if much silver, a yellow and opaque glass. The following

GOLD.

analyses from Rammelsberg's *Chem. Minera.* show the varying proportion of these two metals. Nos. 1 to 5 are by Boussingault, Nos. 6 to 14 by G. Rose.

	Gold.	Silver.
1. Crystal from Transylvania.....	64.52	35.84
2. " " Marmato.....	73.45	26.48
3. Grain from La Vega de Supia.....	82.10	17.90
4. " " near "	88.58	11.42
5. Lamina from Bucaramanga.....	98.00	2.00
6. Gold from Vöröspatak.....	60.49	38.74
7. Crystals from Titiribi.....	76.41	23.12
8. G. from Boruschka, near Nischne Tagil	83.85	16.15
9. G. from near Bogoslawsk	86.81	13.19
10. G. from near Miask.....	89.35	10.65
11. Crystals from Beresow	91.88	8.03
12. Crystal from Katharinenburg	93.34	6.28
13. G. from Boruschka	94.41	5.23
14. G. from near Katherinenburg	98.96	0.16

Awdejew examined crystals from the gold-washing of Katharinenburg, and found them composed as follows:

	Spec. grav.	Gold.	Silver.	Copper, iron, and loss.
Dodecahedral.....	18.89	95.30	3.86	0.84
"	18.00	91.21	8.03	0.76
Tetrahedral	16.03	79.00	20.34	0.66
Octahedral	15.63	70.86	28.30	0.84

All these analyses confirm Rose's conclusion that gold and silver as isomorphs are not combined in definite proportions; but Awdejew thinks from his results (see above) that the form of the crystal is influenced by their relative proportions.

Local. Gold is found in grains, laminæ, and larger masses, disseminated in gravel and sand, derived from the disintegration of veins. It is usually associated with talcose rocks, its immediate gangue being quartz. Its original position seems to be in iron or arsenical pyrites. The alluvial deposits are washed for gold; the veins are regularly mined. Small quantities of gold are found in Germany, France, Britain, &c. Larger amounts are obtained from Hungary. The quantities found on the Ural have so increased, that it is supposed that the value of the same weights of metal will be lowered. It is in this deposit that the largest specimens have been found, one obtained in 1842 weighing 100 lbs. Troy. Gold is also found in many places in the interior of Asia, Africa, and in Australia. In Mexico and S. America, it is chiefly obtained by washing alluvial deposits; one piece is said to have been found in Paraguay weighing 50 lbs. In the U. S. it has been observed in Maine, N. Hampshire, and Vermont, and in a nearly continuous line from Pennsylvania to Alabama, along the more or less altered rocks, and is worked from the Rappahannock in Virginia to the Coosa in Alabama, both by alluvial washing and from veins. The pyritous ores have not yet been worked. See *GOLD*, *Chem.*

scribed in 1685 by Cassius and son; the fuller knowledge of its properties is due to the present century. It occurs disseminated in gravel and sand, due to the disintegration of rocks; in iron and copper pyrites, in galena; combined with tellurium in *GRAPHIC*, *WHITE*, and *FOLIATED TELLURIUM*. See the preceding article.

METALLURGIC TREATMENT OF GOLD ORES.

Testing. The simplest method of testing auriferous sand is to wash over carefully and repeatedly with water, agitating the vessel so that the gold particles may subside, and decanting the water so as to carry off the fine sediment; then to pulverize the residue finely and wash again, repeating this operation until all the gangue is washed away and only gold remains. Vein gold not containing pyrites may be similarly treated, beginning with pulverization. If the ore abound in pyrites, the best method is to pulverize, roast thoroughly, wash over, pulverize and wash again, until the gangue is nearly all washed away. The former method gives a tolerably close analysis, but it is more accurate in both cases to wash the greater part of the gangue away, dissolve the residue in aqua regia by the aid of heat, evaporate to a small bulk to get rid of nitric acid by adding muriatic during evaporation, filter, add a clear solution of copperas to the clear solution, and after standing 24 hours, decant the greater part of the liquor with care from the precipitated gold, treat the residue by heat with muriatic acid, filter, wash, burn the filter, and weigh the pure gold. Not less than 1 or 2 lbs. of poor ore should be employed, unless with a very sensitive balance; and if the gold do not precipitate at first, indicated by a momentary darkening of the solution, it will do so by standing. Very rich ores may be smelted directly with borax, or litharge,

and in the latter case a little charcoal will reduce a portion of the lead, which then takes up gold and silver, and must be cupelled.

Extraction. A. Siliceous ores. 1. Washing sand. Auriferous sand is sometimes washed by hand (in Africa, Hungary, &c.) over an inclined plane with transverse parallel grooves, in the lowest of which the gold particles will be found mixed with sand; this should be pulverized and washed again to get pure gold.

2. Stamping ores. Sand and gravel are sometimes washed by machinery, whereby the pebble and gravel are removed by sifting, and the fine sand washed as above, by the machinery. But the sand and vein ore are more frequently stamped fine with water, and the fine sand and mud stirred with mercury to amalgamate the gold. The sand is washed off, the liquid amalgam pressed in bags of fine canvas or buckskin, and the solid amalgam remaining distilled, mercury passing over, and gold being left in a spongy state. Much mercury is lost if it be introduced into the stamping mill, and hence the employment of several mills, Chilian, Mexican, Tyrolesian bowls, &c., to amalgamate the gold contained in the sand after leaving the stampers. A considerable quantity of gold is lost by any one of these arrangements, and a better plan is to amalgamate in revolving barrels. About 6 dwts. gold to the bushel pays the cost of extraction in the U. S.

B. Rich ores. These may be first powdered and washed, and the residue smelted with borax, litharge, or other fluxes, or they may be picked by hand, powdered, and directly smelted.

C. Pyritous ores. 1. These are sometimes pulverized finely, and washed over to a small very rich residue. The pyrites deposited from the water is washed again, once or twice, then exposed for months in heaps to the air, again ground, and washed over. This process is very imperfect. *2.* The pyrites is first roasted, then ground, and amalgamated; or it is smelted to concentrate it, with or without previous roasting, the resulting stone ground and amalgamated. *3.* The pyrites is smelted, with or without previous roasting, and the ground stone then fused with lead, which is eliquated and cupelled. If copper pyrites predominate, amalgamation is better than imbibition with lead and eliquation.

Parting. The gold obtained by any of these processes usually contains silver, which must be parted or separated, either in the dry or wet way. *A. Dry parting. 1.* With sulphur. The impure gold is fused and granulated in cold water, mixed with $\frac{3}{8}$ to $\frac{1}{2}$ of its weight of sulphur, kept heated for 2 hours or more without fusion, to form sulphuret of silver by cementation, then highly heated to fusion for 1 hour, to perfect the production of sulphuret and the separation of silver richer in gold; a little litharge is then added gradually, and the crucible slowly cooled, during which the greater part, $\frac{5}{8}$ to $\frac{6}{7}$, of the gold with silver collects at the bottom (king), and is separated by a hammer from the upper sulphuret of silver and lead (called plachmal) containing $\frac{1}{8}$ to $\frac{1}{4}$ of the gold; the plachmal is several times fused with litharge until all the gold is extracted. The

king is fused with sulphur, &c., and when rich enough, subjected to quartation; the plachmal is fused with iron, forming sulphuret of iron and silver, which is refined.

2. With crude antimony. The alloy is fused in a glazed crucible with twice as much crude (sulphuret of) antimony, to which, when the content of silver is more than $\frac{1}{2}$, a suitable quantity of sulphur is added. The sulphur unites with the silver, copper, &c., and the antimony with the gold, the latter alloy sinking to the bottom. If the gold contain much silver, this operation is repeated, with less antimony, after previous calcination. By calcination in a muffle, the antimony is driven off as oxide; the alloy may be smelted with saltpeter, which is apt to occasion more loss of gold. The gold after calcination is fused with $\frac{1}{2}$ borax, $\frac{1}{4}$ saltpeter, and $\frac{1}{4}$ glass powder.

3. An obsolete method of parting consisted in stratifying the rolled or granulated alloy in a cement box with regal cement, composed of 4 pts. brickdust, 1 pt. common salt, and 1 pt. calcined copperas, and giving a slowly increasing heat for 18 to 24 hours. The sulphuric acid set free from the vitriol disengaged from the salt muriatic acid, which formed chloride of silver and left a finer gold. The last was then cemented with saltpeter and common salt, whereby the remainder of the silver was extracted.

B. Wet parting. Parting by acids is superior to dry parting. *1. Sulphuric acid.* This process, chiefly adopted in France, consists in heating the granulated alloy with oil of vitriol in cast-iron vessels (or in less strong acid in platinum), whereby sulphate of silver, copper, &c. is formed and dissolved, and gold left, which is again treated with sulphuric acid, washed, dried, and fused with saltpeter in black lead pots. This process is well adapted to large operations.

2. Quartation is performed by nitric acid, which, when free from muriatic or nitrous acid, dissolves silver and not gold, provided the alloy contain 3 pts. silver to 1 pt. gold. If it contain less silver, a portion must be added; if copper be present, the alloy must be cupelled. See ASSAY for the details of the operation. This process is only adapted for silver containing gold in nearly due proportion.

3. By aqua regia. Gold containing silver is treated with aqua regia made by mixing 1 pt. nitric acid of 32° B. (spec. grav. 1.28) and 4 pts. muriatic acid of 22° B. (= 1.178). The granulated or laminated alloy is put into a flask, 3 or 4 times its weight of aqua regia poured over it, and digested until vapors cease to rise. The clear solution is poured off, the residue treated with 1 to 2 pts. aqua regia, this poured into the first, and the residue, chloride of silver, washed in the flask and then on a filter. A solution of copperas is then added to the gold solution, whereby metallic gold is precipitated, which is digested with dilute muriatic acid, washed, and fused with borax and saltpeter.

Alloys and non-saline compounds.

1. Gold. The precipitated powder is brown, dull yellow, with metallic streak, and may be

welded like platinum. The solid metal is yellow, takes a high lustre, is softer than silver, less coherent, and slightly elastic; the most ductile and malleable of all metals, 1 grain may be drawn into a length of 500 ft., or hammered into leaves of more than 50 square inches surface, and $\frac{1}{300000}$ of an inch thick; spec. grav. of the melted metal 19.2; of the hammered 19.4 to 19.65; fusible with considerable expansion at 2200°, scarcely vaporizable by the oxyhydrogen blowpipe, and contracting on cooling more than any other metal. Its affinities are in general feeble, and it dissolves in no single acid, but readily in nitromuriatic or nitrofluoric acid; it readily alloys with arsenic, mercury, and other metals. Sym. Au. Eq. 199. Berzelius regards the equiv. Au as Au₂; the atom is therefore 99.5 or 1243.013 on the oxygen scale.

2. *Oxide of gold.* AuO. Formed by boiling peroxide or perchloride of gold with a solution of caustic or carbonated fixed alkali, or by precipitating the terchloride by dinitrate of mercury. A dark-green powder (Berz.); violet (?) (Figuier); decomposes instantly by chlorohydric acid into perchloride and metallic gold; does not combine with acids.

3. *Peroxide of gold.* Syn. Tritoxide of gold, Auric acid. Form. AuO₃. Prep. Terchloride is not perfectly precipitated by alkali; and baryta used as a precipitant is extracted with difficulty. Digest terchloride with a slight excess of magnesia or oxide of zinc, which throws down nearly all the gold with magnesia or zinc, wash the precipitate with water, and digest with strong nitric acid, which leaves black or brown anhydrous oxide of gold, and dissolves magnesia, with some gold. By digestion with dilute nitric acid, reddish hydrated oxide is obtained. It should be dried without heat; the hydrated oxide, dried at 212°, loses water, becoming black, anhydrous, and is partially reduced. It is soluble in chlorohydric acid; by digestion with tincture of potassa, it is reduced to fine metallic gold; it is readily reduced to metal below a red heat, and even partially reduces by keeping in the dark, more perfectly and rapidly in sunlight.

Purple oxide. For the preparation and use of gold for red glass, see Colored Glass. Some hold that the purple body is metallic gold in a state of exceeding fineness, for when gold is thrown down from very dilute solutions in the metallic state, the liquid sometimes appears for a moment purplish red, and the heat at which this body communicates a red color to glass ought to reduce the gold to the metallic state. Berzelius holds that the purple body thrown down from terchloride of gold by dinitrate of mercury is a chloride intermediate between proto and terchloride, and that the red color of the glass is due to the corresponding oxide; for although oxide of silver is easily reduced by heat, yet this oxide communicates a yellow color to glass.

Purple of Cassius. Prep. 1. To a solution of perchloride of iron add a solution of protochloride of tin, until the yellow color passes into a pale green, and add this solution to a gold solution freed from nitric acid. (Fuchs.) 2. Dis-

solve gold in aqua regia, evaporate with an excess of muriatic acid to expel all the nitric, and dilute largely with water. The necessary dilution is ascertained by dipping a glass rod in a solution of sesquichloride of tin and then into the gold solution; if the precipitate redissolve by agitation, it is sufficiently diluted. Then add a solution of sesquichloride of tin in small portions with stirring until there is no more chloride of gold remaining, and avoid an excess of tin salt. The liquid is deep brown, or purplish red, and after standing 24 hours deposits the purple, which is then filtered and washed. (Berzelius.) 3. Dissolve 1 pt. tin in muriatic acid, not in excess; dissolve 2 pts. tin in a cold mixture of 3 nitric and 1 muriatic acid, and warm the solution at last, so as to make perchloride of tin; dissolve 7 pts. gold in nitromuriatic acid (6 muriatic and 1 nitric) and dilute the solution with 3500 pts. water. Add the perchloride of tin to the gold solution, and then the protochloride by drops until the proper color is attained. (Buisson.) 4. Warm 10 pts. perchloride of tin and ammonium with 1.07 pts. tin and 40 water, until the tin is dissolved, and add 140 pts. water; dissolve 1.34 pts. gold in nitromuriatic, not in excess, and dilute with 48 pts. water; pour the former into the latter as long as it produces a precipitate; filter, wash, and dry at 212°.

Prop. Brown or dark purplish red, soluble while still moist, in ammonia, with a deep purple color, from which it separates by adding acid or by boiling; the ammoniacal solution heated in a close flask from 140° to 176°, deposits purple rapidly without redissolving it; if evaporated, the precipitate, although apparently unchanged, is insoluble in ammonia; the solution gradually decomposes in light, depositing metallic gold. The purple retains water at 212°, but loses it by ignition, giving off no fixed gas, and becoming brick-red; by fusion with saltpeter, it forms stannate of potassa and a bead of alloy of gold and tin; nitromuriatic acid extracts all the gold and a little tin, leaving peroxide of tin. Different views are entertained of the composition of the purple; it is terstannate of protoxide of gold, AuO, 3 SnO₂ + 4 HO, with 42.5 pr. ct. gold (Figuier); or hexastannate of protoxide, AuO, 6 SnO₂ + 6 HO, with 28 pr. ct. gold (Figuier); or protostannate of tin and gold, SnO, 3 SnO₂ + AuO, 2 SnO₂ + 6 HO (Schweigger-Seidel); or stannite of binoxide of gold, AuO₂ 2 Sn₂O₃ + 4 HO, with 39 pr. ct. gold (Berzelius); or it is sesquioxide of tin and stannate of binoxide of gold, 2 (SnO, SnO₂) + AuO₂, 2 SnO₂ + 6 HO, with 28 pr. ct. gold. (Fuchs.) As mercury extracts no gold from it, the latter must be oxidized; the perchloride of tin does not precipitate the purple from perchloride of gold, but the protochloride does; and therefore the gold or tin, or both, must be in a lower state of oxidation; a stannate of protoxide of gold would probably give off oxygen, which the purple does not, and it is therefore either stannate or stannite of a higher oxide of gold, probably AuO₂. From its not giving oxygen, the probability is that Berzelius' view is the most correct, for the deutoxide of gold would merely convert the sesquioxide of tin into the deutoxide and metallic gold;

$\text{AuO}_2, 2 \text{Sn}_2\text{O}_3 = \text{Au} + 4 \text{SnO}_2$. The purple is largely employed for imparting a brilliant red to glass, and for painting porcelain and enamel of a pink or rose color.

4. *Sulphuret of gold.* AuS . Pass sulphohydric acid through a boiling solution of terchloride. It is black with a dark-brown streak, and contains 92.5 pr. ct. of gold. The *persulphuret*, AuS_3 , formed by passing sulphohydric acid through a cold dilute solution of terchloride, is black; by precipitating the sulphaurate of potassium by acids, it forms yellow floculæ. Both sulphurets are easily decomposed by heat, leaving metallic gold. The last dissolves partially in caustic potassa. The persulphuret dissolves readily in a solution of sulphuret of potassium, and acts as a sulphacid to the other positive sulphurets, but as a sulphobase to the negative sulphurets of arsenic, molybdenum, &c. The *sulphocarbonate*, $\text{AuS}_3, 3 \text{CS}_2$, forms a black precipitate by bringing together the terchloride and sulphuret of carbon, both in solution.

5. *Phosphuret of gold.* Gold and phosphorus readily combine to a nearly white metallic compound, more fusible and brittle than gold; it may also be formed by heating gold with phosphoric glass and charcoal. By heating in the air the phosphorus burns.

6. *Fulminating gold.* There are two kinds, one containing chlorine explodes less, the other without chlorine more violently. The former is made by digesting terchloride of gold with an excess of caustic ammonia, washing the yellow precipitate with warm water until the filtrate ceases to test of chlorine, and drying in a water-bath. It is a dark-yellow powder, detonating when heated to 400° . The other, without chlorine, is made by digesting the former in a mixture of potassa and ammonia, until it changes to a yellowish brown, which becomes deeper by washing and drying. It is also made by digesting oxide of gold in ammonia or its salts. It explodes violently at 212° , by friction, stroke or electricity; if moist it is far less explosive, and by mixture with indifferent bodies (20 pts. sulphate of potassa, silica, magnesia, &c.). Its composition is $\text{AuO}_3 + 2 \text{NH}_3 + \text{HO}$ (*Berzelius*); $\text{AuN} + \text{NH}_3 + 3 \text{HO}$. *Dumas*.

7. *Alloys of gold.* Gold combines readily with arsenic, even in vapor, forming a gray, brittle alloy, containing $\frac{1}{241}$ pt. arsenic, which cannot be wholly expelled by 2 hours fusion in an open crucible. $\frac{1}{6000}$ pt. arsenic renders gold brittle without altering its color. The alloy with $\frac{1}{9}$ antimony is pale and brittle, and the antimony may be wholly expelled by heat; $\frac{1}{10000}$ antimony destroys the malleability of gold. *Telluret* of gold is formed by precipitating terchloride by telluret of hydrogen or potassium, or by heating sulphotellurite of gold. It also occurs native in GRAPHIC and WHITE TELLURIUM.

The *platinoid* metals readily unite with gold to alloys, which are brittle and paler, unless the gold be in considerable excess; very little palladium or platinum pales gold, and 6 pts. gold to 1 palladium is nearly white.

Gold and silver alloy in every proportion, with a color and spec. grav. nearly correspond-

ing to the proportion. The alloy is harder, paler and more fusible than gold, the hardest consisting of 2 pts. gold to 1 pt. silver. See GOLD, MIN.; ALLOY, ASSAY. Mercury readily alloys or amalgamates with gold in variable proportions, at least one of which is a definite alloy crystallizing in dendrites or 4-sided prisms, and composed of AuHg_{12} , or 1 pt. gold to 6 pts. mercury. It is solid, and is obtained in amalgamating gold ores, by pressing its suspension in excess of mercury through porous materials. When heated, all the mercury is expelled, leaving pure gold, and on this depends the process of fire-gilding.

Gold unites with copper in every proportion, but forming one crystalline alloy composed of Cu_2Au . Copper exerts little influence upon its malleability, but reddens its color; the addition of a little silver obviates the reddening, or heating it in strong caustic ammonia. Common gold may contain 25 pr. ct. copper and silver. Cupellation with lead will not remove all the copper, unless 3 pts. silver and 24 pts. lead be first fused with it.

Eleven pts. gold to 1 bismuth forms a greenish yellow, very brittle, fine-grained alloy, of spec. grav. 18.038. 11 gold to 1 lead is pale yellow, exceedingly brittle, fine-grained, of spec. grav. 18.08. $\frac{1}{1900}$ pt. bismuth or lead renders gold brittle. Both can be separated from gold by cupellation.

Eleven gold to 1 zinc is pale greenish yellow, brittle, of spec. grav. 16.937; 1 gold, 1 zinc, is very white and hard; even 60 gold and 1 zinc is brittle; 1 pt. brass renders gold brittle. 11 gold to 1 tin gives a very pale-yellow alloy, slightly ductile, of spec. grav. 17.307; they are best separated by fusion with crude antimony.

One pt. gold to 4 pts. iron is silver-white; 1 gold to 1 iron is gray; 11 gold to 1 iron is yellowish gray, hard, very malleable, spec. grav. 16.885. Gold does not improve the quality of steel. 7 or 8 gold to 1 manganese is pale yellowish gray, very hard, less fusible than gold, slightly malleable. 18 gold to 1 cobalt is dark-yellow, very brittle, 64 to 1 is still brittle, 109 to 1 is ductile. Gold combines readily with nickel to a yellowish white, hard, very malleable alloy, as magnetic as nickel itself.

Uses. Gold possesses intrinsic value independently of its rarity. Its color, high specific gravity, ductility and malleability, fusibility, and resistance to chemical action, especially to atmospheric agents, render it very valuable, and the best medium of exchange. Pure gold is too soft for use as coin or plate, and hence the advantage of alloying it with copper, while its specific gravity offers a mean of testing its quality. Although a rare metal, its exceeding malleability allows its extensive employment for gilding surfaces at little cost, while its unalterability prevents such surfaces from readily tarnishing. For many objects of ornament and utility, electrotyping gilding has superseded leaf and fire-gilding.

Salts of Gold.

Gold has so little tendency to combine with acids, that but few salts of gold have been studied. The sulphosalts see under the sulph-

acids of ARSENIC, MOLYBDENUM, TELLURIUM, and TUNGSTEN. Oxide of gold is dissolved by sulphite or hyposulphite of potassa or soda, forming double salts of mono and dithionites of soda and protoxide of gold. *Fordos* and *Gelis*, and *Himly*.

The haloid salts are most numerous and best known. They are of a yellow or orange-color; precipitate the purple of Cassius, when very dilute, by protochloride of tin, and metallic gold of a brown color by protosulphate of iron and other deoxidizing agents.

1. *Chlorides*. a. The *protochloride*, AuCl , formed by evaporating the *terchloride* and heating it in porcelain to about 450° , with constant stirring, until chlorine ceases to be evolved, is yellowish white, easily decomposed by a higher heat into chlorine and gold, by hot water into *terchloride* and metallic gold, by potassa into *chloride* of potassium and protoxide of gold. It forms a double salt with *chloride* of potassium, by heating the double *terchloride* of gold and potassium. By adding *terchloride* of gold in successive portions to hyposulphite of soda until the yellow color disappears, and evaporating to crystallization, the greater part of hyposulphite and sulphate of soda separate. The liquid again crystallized yields among others colorless needles, which by solution in alcohol of 0.9, and spontaneous evaporation, yield the same crystals. They are probably dithionite of soda and gold.

b. *Terchloride* is the most important salt of gold, and is obtained by dissolving gold in aqua regia and evaporating the excess of acid. The acid salt yields crystalline needles, which are easily decomposed by heat. The solution of gold is best made with an excess of metallic gold, which ensures the destruction of all the nitric acid. It is yellow when dilute, orange when concentrated. The solution is reduced in part in a close glass vessel, by exposure to light, on which side metallic gold deposits. It is reduced by phosphorus, hydrogen, phosphohydrogen, sulphurous acid and the sulphites, nitric oxide, peroxide of nitrogen and nitrite of potassa, in the cold, and by sulphur and selenium in heat. It is reduced by almost all metals, by arseniuretted and antimoniuiretted hydrogen, *terchloride* of antimony and white arsenic, and protosalts of iron. *Protochloride* of tin precipitates brown gold-tin from a strong, and purple (Cassius') from a dilute solution; protonitrate of mercury gives a dark-blue precipitate. It is also reduced by most organic bodies, whether in solution or not, especially by the addition of potassa. Potassa, soda, strontia, lime, magnesia, and oxide of zinc, throw down the greater part of the gold as an impure oxide, or a basic salt, of which the precipitate by the two last is easily purified by nitric acid. Sulphuretted hydrogen throws down sulphuret of gold, soluble in alkaline sulphurets. Ammonia precipitates fulminating gold.

Chloraurides. The *terchloride* combines with nearly all metallic *protochlorides* by direct union, forming compounds which contain 3 eq. chlorine in the *chloracid* to 1 eq. chlorine in the *chlorobase*. In the crystallized state they are almost all orange-colored, lighter yellow

low by efflorescence, but deep-red when anhydrous.

Chlorauride of potassium forms rhombic prisms or 6-sided tables, efflorescent, losing all water at 212° without farther decomposition, at a higher heat becoming double *protochlorides*; soluble in water and alcohol. Form. dry, KCl , AuCl_3 (52.4 pr. ct. gold); cryst. KCl , $\text{AuCl}_3 + 5 \text{HO}$ (46.84 pr. ct. gold). The salt of sodium is permanent in the air. NaCl , $\text{AuCl}_3 + 4 \text{HO}$ (dry 54.7, cryst. 49.78 pr. ct. gold). The lithium salt is deliquescent; that of ammonium with 2 eq. water, made with neutral gold solution, is yellow, and by solution in aqua regia, red. The salts of barium, strontium, calcium, magnesium, zinc, manganese, cobalt, nickel, and cadmium, are yellow rhombic prisms, of cobalt dark yellow, of nickel greenish yellow; of strontium, zinc, cadmium, cobalt and nickel permanent, the rest somewhat deliquescent; that of calcium contains 6 eq., of magnesium 12 eq. water.

2. *Bromides*. *Terbromide of gold*, formed by dissolving gold in nitro-bromhydric acid, forms by evaporation a red saline mass, which combines with most simple bromides to form double salts or bromaurides, analogous to the chloraurides, containing water, but of purple or brownish red colors.

3. *Iodides*. a. *Protiodide of gold*, AuI , is formed, 1. by the action of *iodohydric acid* on oxide of gold, whereby iodine is set free and may be volatilized by boiling the solution; $\text{AuO}_3 + 3 \text{HI} = \text{AuI} + 3 \text{HO} + 2 \text{I}$. 2. By the action of *iodohydric acid* in excess on finely divided gold, with the addition of small portions of nitric acid; the liquid, filtered boiling, separates most of the salt on cooling as a yellow powder, and the balance is obtained by heating the liquid with nitric acid until all iodine disappears. 3. Add iodide of potassium to *terchloride* of gold carefully, until it ceases to precipitate; $\text{AuCl}_3 + 3 \text{KI} = \text{AuI} + 3 \text{KCl} + 2 \text{I}$; wash with alcohol and then with water. It is a yellowish crystalline powder, not readily decomposed by acids excepting when heated, instantly decomposed by alkali, decomposed by *iodohydric acid*, iodide of potassium and of iron, with the separation of gold and formation of *teriodide*.

b. *Teriodide*. Add *terchloride* of gold gradually to iodide of potassium in dilute solution, until it is dark green; agitate the liquid until the precipitate is redissolved, and add more *terchloride*, which precipitates the *teriodide*. It is dark green, easily decomposed, dissolves in *hydriodic acid*, forming a dark reddish-brown crystallizable solution, and unites with basic iodides to form *iodaurides*, which are black and crystallizable.

GONG. A large plate-shaped cymbal, used in China as a substitute for bells. The metal of which they are composed is copper mixed with 20 to 25 pr. ct. of pure tin. See *Tempering*, &c. under BRONZE, on which the peculiar ring of the gong depends. See also ALLOY.

GONIOMETER. *Cryst*. An instrument for measuring the angles made by planes of crystals with each other. Two kinds are used, the direct or common, and the reflecting. The *Common Goniometer* consists, as represented in

Fig. 83.

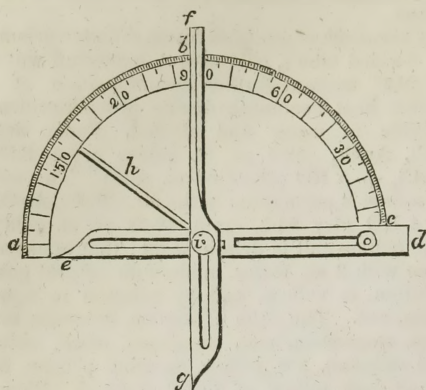
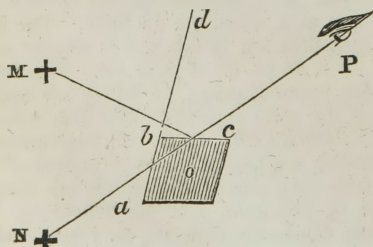


fig. 83, of a brass or silver semicircle abc , graduated into 180° , each degree being marked on the instrument by a short line extending from the outer rim to the circle, which is about one-twentieth of an inch within it; de and fg are two steel arms, the horizontal one being fixed, the vertical movable; beneath the arm de , a plate of steel or brass is attached to the semicircle near c , and extends somewhat more than half-way towards a , its termination being connected with the semicircle by the bar h for the sake of firmness: i is the head of a pin in the centre of motion, equidistant from all points of the semi-circumference, and passes through both arms and the brass plate; on this pin the arm fg is moved at pleasure. The upper part of the arm fg cuts the semicircle in the figure precisely at 90° ; if then two faces of a cube were presented to the lower portions of the two arms gi and ie , it would be found to fit them accurately, since the planes of a cube always meet each other at the angle of 90° . But if the solid be less or more than that angle, the instrument may be accommodated to the angle by moving the arm fg by its termination f ; and the value of the angle will be indicated by the edge of the movable arm. If the crystal be small and surrounded by obstruction, the two arms may be drawn by the ends d and f , so that the points g and e will be much nearer the pin i . Sometimes this goniometer is made in two parts, the semicircle being one of them, and the two arms, connected by the pin, the other. The arms are then separately adjusted to the crystal, and being secured, the pin is dropped into the hole made to receive it. *Phillips.*

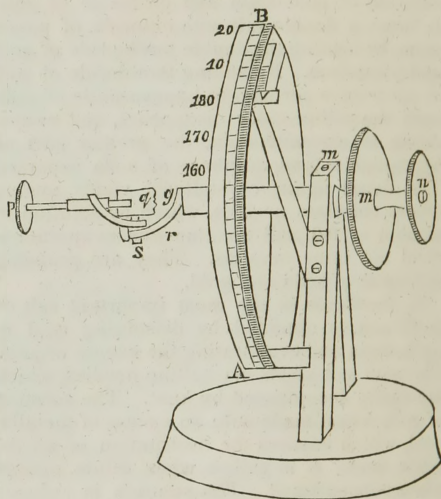
Since in a majority of cases the reflection of the natural or cleaved surfaces of crystals is very distinct, Dr. Wollaston contrived the *Reflecting Goniometer*, which is very superior to

Fig. 84.



the common goniometer in such cases. Fig. 84 represents the principle on which this instrument operates. The angle abc is required. The eye at P , looking at the face of the crystal, bc , observes a reflected image of M , in the direction of PN . The crystal may now be so changed in its position, that the same image is seen reflected by the next face, and in the same direction, PN . To effect this, crystal must be turned around, until abd has the present direction of bc . The angle dbc measures, therefore, the number of degrees through which the crystal must be turned. But dbc , subtracted from 180° , equals the required angle of the crystal abc . The crystal is therefore passed in its revolution through a number of degrees, which, subtracted from 180 , give the required angle. Fig. 85 repre-

Fig. 85.



sents the goniometer. AB is the circle graduated to half degrees. By means of the vernier, v , minutes are measured. The wheel m is attached to the main axis, and moves the graduated circle, together with the adjusted crystal. The wheel n is connected with an axis which passes through the main axis (which is hollow for the purpose), and moves merely the parts to which the crystal is attached, in order to aid in its adjustment. The contrivances for the adjustment of the crystal are at p, q, r . To use the instrument, it must be placed on a small stand or table, and so elevated, as to allow the observer to rest his elbows on the table. The whole, thus firmly arranged, is to be placed in front of a window, distant from the same from six to twelve feet, with the axis of the instrument parallel to it. Before operation, a dark line should be drawn below the window near the floor, parallel to the bars of the window; or, what is still better, on a slate or board placed before the observer on the table.

The crystal is attached to the movable plate, q , by a piece of wax, and so arranged, that the edge of intersection of the two planes, including the required angle, shall be in a line with the axis of the instrument. This is done by varying its situation on the plate q , or the

situation of the plate itself, or by means of the adjacent joints and wheel, *r*, *s*, *p*.

When apparently adjusted, the eye should be brought close to the crystal, nearly in contact with it, and on looking into a face, part of the window will be seen reflected, one bar of which must be selected for the experiment. If the crystal is correctly adjusted, the selected bar will appear horizontal, and on turning the wheel *n*, till this bar, reflected, is observed to approach the dark line below seen in a direct view, it will be found to be parallel to this dark line, and ultimately to coincide with it. If there is not a perfect coincidence, the adjustment must be altered until this coincidence is obtained. Continue then the revolution of the wheel *n*, till the same bar is seen by reflection in the next face, and if here there is also a coincidence of the reflected bar with the dark line seen direct, the adjustment is complete; if not, alterations must be made, and the first face again tried. A few successive trials of the two faces, will enable the observer to obtain a perfect adjustment.

After adjustment, 180° on the arc should be brought opposite 0, on the vernier. The coincidence of the bar and dark line is then to be obtained, by turning the wheel *n*. As soon as obtained, the wheel *m* should be turned until the same coincidence is observed, by means of the next face of the crystal. If a line on the graduated circle now corresponds with 0 on the vernier, the angle is immediately determined by the number of degrees marked by this line. If no line corresponds with 0, we must observe which line on the vernier coincides with a line on the circle. If it is the 18th on the vernier, and the line on the circle next below 0 on the vernier marks 125° , the required angle is $125^\circ 18'$; if this line marks $125^\circ 30'$, the required angle is $125^\circ 48'$.

Some goniometers are furnished with a small polished reflector attached to the foot of the instrument, below the part *s* *q*, and placed at an oblique angle so as to reflect a

bar of the window. The reflector may be easily added to the common instruments, placing it at an angle of about 45° , or such as will reflect the bar to the eye, when looking towards the crystal while observing.

Fig. 86 represents an improved arrangement for adjusting the crystal, drawn from a German instrument. The contrivance *a c d* is also an important addition. It contains a slit at *d* for sighting the crystals, by using which, one of the lines may be dispensed with. It slides up and down in the part *a b*, and also moves back and forth, parallel with the plane of the graduated circle, on the pivot by which it is attached to the stand of the goniometer. *Dana*.

GÖTHITE. See **BROWN HEMATITE**.

GOULARD'S EXTRACT. See **LEAD**.

GRAMMATITE. See **HORNBLENDE**.

GRAMMITE. See **TABULAR SEAR**.

GRANITE. *Geol.* A rock composed of quartz, feldspar and mica. It is generally believed to be the original rock from which others are derived, and to have been in a fused state. Hence its crystalline structure. It is an excellent building-stone, and from the absence of stratification or lamination is obtainable in large masses. Syenite and other igneous rocks are popularly called granite. See **GEOLOGY**.

GRANULAR. *Min.* A mineral is said to be granular, when it consists of coarser or finer sandy particles, more or less coherent. This structure is due to imperfect **CRYSTALLIZATION**.

GRANULATION. This term, as applied to metals or fusible substances, expresses their comminution into fine particles or grains. The usual process of effecting this is to pour the melted body into water agitated simultaneously by a twirl-stick or stirrer. The manufacture of shot is an instance of granulation, though in this instance the granules are by a suitable arrangement made to take a spherical form and uniform size. Granulation increases the surface of bodies, and is thus advantageous where they are to be submitted to the action of reagents. The separation of the molecules of a solid body from a liquid in which it is intimately suspended, is also termed granulation, as in the instance of the separation of stearin from olein in preparing lard for the expression of its oil. This, however, more properly, is a species of crystallization, which must be promoted by a certain temperature.

GRANULITE. See *Granite* under **GEOLOGY**.

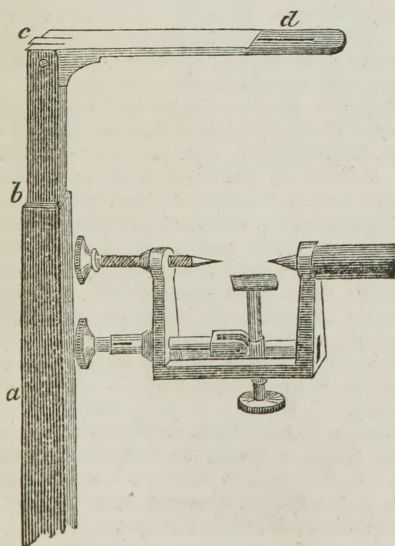
GRAPHIC GOLD. See **GRAPHIC TELLURIUM**.

GRAPHIC GRANITE. *Geol.* Is granite mainly composed of feldspar, with quartz disseminated through it, so as to resemble written characters on a cleaved surface.

GRAPHIC TELLURIUM. *Min.* Syn. Graphic Gold, Schriftez. Cryst. Right Rhombic; cleavage very perfect parallel to vertical prism, less perfect parallel to main end-plane; also columnar and granular. *H.* = 1.5 — 2. *G.* = 6 — 8.28. Color and streak, steel-gray; metallic; fracture uneven; very sectile.

Chem. Rel. Alone on charcoal it melts to a

Fig. 86.



GRAPHITE.

dark-gray metallic globule, depositing a white coating, which disappears with a greenish light by directing the flame upon it; by long blowing, a yellow, malleable globule remains, which at the moment of cooling becomes white hot; in an open tube it deposits white fumes, which fuse, when heated, into transparent drops. It is soluble in aqua regia, depositing chloride of silver; the solution becomes milky by dilution. Form. $\text{AgTe} + 2\text{AuTe}_3$, containing about 60 tellurium, 27 gold, and 13 silver. It appears to be the same with WHITE TELLURIUM. It occurs at Offenbanya, Transylvania, and at Nagyag.

GRAPHITE. *Min.* Syn. Plumbago, Black Lead, Carburet of Iron. *Ger.* Reissblei. *Cryst.*

	1.	2.	3.	4.	5.
Carbon.....	53.4	62.8	71.6	94.6	99.67
Iron.....	7.9	..	5.0	..	} 0.33
Lime and alumina.....	36.0	37.2	8.4	6.0	
Silica, &c.	2.7	..	1.5	..	

Local, &c. Some of the finest quality for pencils is found at Cumberland, Engl., and the different degrees of hardness is usefully applied to pencils for sketching, shading, &c. It is generally contained in primary rocks, and in the older, altered limestones, whose lead-gray color is due to it. Fine specimens are found near the head of Lake Champlain. Scales of graphite are sometimes substituted for mica in gneiss, and constitute an extensive graphite formation, as in N. Carolina, where large blocks can be quarried out. There are numerous other localities of graphite. Besides its use for pencils, it is an important constituent in the black-lead crucible. See CRUCIBLE.

GRASS OIL. *Syn.* Oil of Namur, Indian-grass Oil. The product of the *Andropogon Iva-racusa*. Odor similar to that of oil of roses. Boiling point from 297° to 320° . The rectified oil consists of C_8H_8 . Its affinity for oxygen is such, that during distillation a portion of it is converted into resin. In its impure state it is composed of two oils, one of which contains oxygen. *Stenhouse.*

GRATIOLA OFFICINALIS. The resinous matter of the herb, considered by Vauquelin as its active principle, consists of tannic acid, *Gratiolin*, and a non-crystalline substance insoluble in water, but soluble in alcohol and ether, and in sulphuric acid with a pale reddish yellow color.

Gratiolin crystallizes from its alcoholic solution in warty groups, and in water and ether is but sparingly soluble. *Marchand.*

GRAY ANTIMONY. *Min.* Syn. Sulphuret of Antimony. *Ger.* Antimonglanz, Grauspiessglanzerz. *Lat.* Stibium, Plumbum nigrum. *Alchem.* Lupus metallorum. *Gr.* Στιμμι. *Cryst.* Right Rhombic, generally in long prisms, longitudinally striated; cleavage perfect parallel to shorter lateral axis; also foliated, granular. $\text{H.} = 2$. $\text{G.} = 2.62 - 2.626$. Color and streak dark lead-gray; metallic; very sectile and brittle, with a subconchoidal fracture.

Chem. Rel. Very fusible, coloring the flame bluish green, volatilizing, coating the charcoal white, and giving the odor of sulphurous acid; in an open tube sublimes antimonious acid,

Hexagonal, with laminated structure. $\text{H.} = 1 - 2$. $\text{G.} = 2.089$. Iron-black, dark steel-gray; lustre metallic; opaque; greasy; sectile, soils paper, and produces a dark lead-gray streak on porcelain, which distinguishes it from molybdenite.

Chem. Rel. Very slowly and only partially burned off by the blowpipe, leaving an ash usually containing iron; deflagrates slightly with saltpeter; acids extract metallic oxides. It is essentially pure carbon, C, with variable quantities of foreign matter, as the following analyses show. 1, English of fine quality; 2, Ceylon, native; 3, from Himalaya; 4, crystallized, from Ceylon—all analysed by Prinsep; 5, Wunsiedel, by Fuchs.

and then oxide of antimony. Soluble in heated muriatic acid, with evolution of sulphuretted hydrogen, and usually leaving chloride of lead; decomposed by nitric acid, with the separation of oxide of antimony; soluble in caustic potassa, forming a yellow solution, which, on adding acid, deposits yellowish red sulphuret. Form. SbS_3 , containing, when pure, 72.77 pr. ct. antimony.

Local, &c. It occurs in numerous localities; very fine specimens are obtained at Felsőbanya, Schemnitz and Kremnitz, Hungary. In the U. S. at Carmel, Penobscot Co., Maine; at Cornish and Lyme, N. H.; at Soldier's Delight, Md.; in the lead mines of Southern Illinois and Kentucky. It is the chief source of ANTIMONY in commerce.

GRAY COPPER. *Min.* Syn. Fahlerz. *Ger.* Kupferfahlerz, Schwarzgültigerz, Schwarzerz. *Fr.* Cuivre gris. *Cryst.* Regular, sometimes 8-hedral, but generally in hemihedral forms, as shown in Pl. VIII. figs. 12, 13 and 14. It is often compounded on an 8-hedral plane, parallel to which it cleaves imperfectly. It also occurs granular. $\text{H.} = 3 - 4$. $\text{G.} = 4.8 - 5.1$. Color between steel-gray and iron-black; streak the same or brownish; metallic; opaque; rather brittle, with subconchoidal fracture.

Chem. Rel. Calcined in an open tube, it gives the odor of sulphurous acid, sometimes of arsenic, and sublimes oxide and acid of antimony. It fuses on charcoal, evolving the same vapors, and by treating the residue with soda and borax, gives a copper globule, which by cupellation yields silver. It is also decomposed by nitric acid, and partially by caustic potassa; from the latter solution, acid separates an orange or yellow sulphuret. Of the following analyses, 1, 2, 5, 7, 9, 10, 11 are by H. Rose, 3 by Scheidthauer, 4 by Kersten, 6 by Bromeis, 8 by Lander. No. 1 is from Markirchen, in Elsass; 2 from Gersdorf, near Freiberg; 3, near Iglo, in Hungary; 4, near Pietra Santa, in Tuscany; 5, Kapnik, in Hungary; 6, Durango, in Mexico; 7 and 8, Klausenthal, on the Hartz; 9 and 10, near Wolfach in Fürstenberg; 11, near Freiberg.

GRAYWACKE.

GREEN EARTH.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Sulphur	26.83	26.33	23.34	24.17	25.77	23.76	24.73	24.1	25.50	23.52	21.17
Antimony ...	12.46	16.52	18.48	24.47	23.94	25.97	28.24	26.8	27.00	26.63	24.63
Arsenic	10.19	7.21	3.98	..	2.88	..	..	..	..	..	..
Copper	40.60	38.63	35.90	35.80	37.98	37.11	34.48	35.7	25.50	25.23	14.81
Iron	4.66	4.89	4.90	1.89	0.86	4.42	2.27	4.5	7.00	3.72	5.98
Zinc	3.69	2.76	1.01	6.05	7.29	5.02	5.55	..	..	3.10	0.99
Silver.....	0.60	2.37	..	0.33	0.62	1.09	4.97	8.9	13.25	17.71	31.29
Mercury	..	..	7.52	2.70	..	Lead, 0.54	..	0.9	..	..	..
	99.03	98.71	95.13	95.41	99.34	97.91	100.24	100.9	98.25	99.91	98.87

Nos. 2, 3, 4 and 6 contained a little quartz gangue.

Gray copper is remarkable from the replacement of many isomorphous sulphobases, and two sulphacids. The sulphuret of mercury in 3 and 4 is probably HgS . That of copper is probably Cu_2S , and it would appear to be isomorphous with sulphuret of silver, AgS . But there are differences of opinion on this point, and it is therefore difficult to establish a formula correctly. Calling the acid SbS_3 , since the quantity of arsenic is generally little or nothing, and sulphurets of iron, zinc, and mercury RS , we have the formula $4\text{RS}, \text{SbS}_3 + 2(4\text{Cu}_2\text{S}, \text{SbS}_3)$. The unvarying proportion of sulphuret of copper in most of the ore, seems to separate its sulphosalt from the rest; but then there is no place for the sulphuret of silver, unless we assume that it partly replaces the copper. By including all the bases together, with Frankenheim, we have the more simple formula, $4\text{RS}, \text{SbS}_3$.

Local. St. Austle, Cornwall; Andreasberg, Hartz; Dillenberg, Nassau; Schwartz, Tyrol, and other places above mentioned. It is worked for silver and gold.

GRAYWACKE. *Geol.* A name for some of the older slates of the lowest secondary rocks, now abandoned.

GREEN EARTH. **GREEN SAND.** *Min.* Under this name are included several substances apparently derived from the decomposition of

augitic and talcose minerals, or allied to chlorite. But it is remarkable that green sand, contained in the upper secondary or lower tertiary formations, often presents an analogous composition, although no connection between it and the green earth has been established, nor are they allied in all their physical characters. The following analyses will show the differences in composition between the true green sand and the green earth. Nos. 1 to 5 are green earth. Nos. 6 to 13, green sand; but 6 and 7 are evidently different from 8 to 13 in their larger proportion of alumina. No. 1 is grengesite from Dalarne, by Hisinger, and contains in addition 2.18 protoxide of manganese; 2 and 3 are by Klaproth, the former from Lossossna, E. Prussia, the latter from Mt. Baldo, the iron is given as peroxide and the 4.5 alkali is soda, but from the green color it is probable that the iron is protoxide; 4 and 5 are pseudomorphs of augite from Fassathal, by Rammelsberg, who estimated $\frac{2}{3}$ of the iron in 4 as peroxide; 6, green sand, by Turner, and 7, from Gay Head, Mass., U. S., by S. L. Dana (ought not 7 water to be added?); 8, green sand in chloritic chalk from Germany, by Berthier, the silica gelatinized, and there are 11.5 of quartz besides in the analysis; 9 to 13 from the U. S., 9 from Poke Hill, Burlington Co., N. J., and 10 from Sculltown, N. J., by H. D. Rogers; 11 and 12 from Delaware, by J. C. Booth, and 13 by C. Morfit.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
Silica	27.81	51.	53	45.87	39.48	48.5	56.7	46.1	50.75	51.50	48.30	56.35	55.9
Alumina	14.31	12.	..	11.18	10.31	17.0	13.3	5.5	6.50	6.40	4.80	6.00	4.9
Protoxide of iron	25.63	17.	28	24.63	24.60	22.0	20.1	19.6	22.14	24.30	26.46	22.25	18.1
Magnesia	14.31	3.5	2	0.28	1.70	3.8	1.2	3.8	..	..	1.50	traces	..
Lime	..	2.5	..	1.50	15.24	..	1.6	..	..	..	..	..	..
Potassa	..	4.5	10	6.72	8.67	..	..	5.3	12.96	9.96	8.63	8.42	8.0
Water	12.53	9.	6	9.82	..	7.0	7.0?	8.9	7.50	7.70	10.79	7.11	12.1
	94.59	99.5	99	100.	100.	98.3	99.9	89.2	99.85	99.86	100.48	100.13	99.

Of these the 1st is allied to **CHLORITE**. The green sands 8—13, from very different localities, appear to point out a definite composition. By calculating No. 11, we have $2(\text{KO}, \text{SiO}_3)$, Al_2O_3 , $2\text{SiO}_3 + 4\{2(\text{FeO}, \text{SiO}_3), 3\text{HO}\}$, the first member of which resembles **ISOPYR**, and the second is sesquihydrate of neutral silicate of iron. An average of 5 analyses seems to point out a similar silicate of iron, but the other member of the formula is different. It remains yet to be ascertained in what manner the substances are united together in green sand.

Use. Green sand has been largely employed in the U. S., especially in New Jersey, Delaware, Maryland, and Virginia, for fertilizing

the crops, an effect which might be inferred from its content of potassa alone. But in addition to potassa, it usually contains a small quantity of lime, and almost always phosphates of iron, lime, alumina, and magnesia. In some localities crystallized phosphate of iron occurs in it in abundance. Its value is enhanced by the hydrous state of the compound, whereby it is more readily acted upon by meteoric agents. It may even be decomposed by carbonic acid. See Report on the Geology of Delaware, by J. C. Booth. This valuable formation extends from near Amboy, in New Jersey, through Delaware, Maryland, and Virginia, but as it traverses southward it becomes more calcareous, passing into a shell-

GREEN IRON-STONE.

marl. It occurs in beds of from 1 to 30 ft. in thickness, and analysis No. 11 was taken from a bed of about 10 ft. thickness and of uniform quality throughout. Spread over poor soils it produces a remarkable effect on the crops; and it may be employed in quantities of from 30 to 300 bushels per acre. See Reports on the Geology of New Jersey by H. D. Rogers, of Delaware by Booth, of Maryland by Ducatel, and of Virginia by W. B. Rogers. Green sand has been also applied to bottle glass, to which it imparts a rich green tint.

GREEN IRON-STONE. *Min.* Syn. Alluaudit. Fibrous; H. = 3; G. = 3.23; dull leek-green, altering by exposure to yellow and brown; lustre feeble silky; subtranslucent. Fusible to a black porous slag; yielding water in a closed tube; gives the reactions of phosphoric acid and iron. Form. $2(2\text{Fe}_2\text{O}_3, \text{PO}_5) + 5\text{HO}$. It occurs in Saxony. (*Kursten*.) The alluaudit of Vauquelin is undoubtedly the same, from Hureaux, France. See **BERAUNITE** and **KARPHOSIDERITE**.

GREENLANDITE. See **GARNET**.

GREEN MALACHITE. See **MALACHITE**.

GREENOCKITE. *Min.* Cryst. Hexagonal, the prism with several 6-sided pyramids; lateral cleavage distinct. H. = 3 — 3.5. G. = 4.9. Orange-yellow color and streak; adamantine; transparent, with strong double refraction. It decrepitates in a closed tube, assuming a passing carmine-color; gives off sulphurous acid, and with soda on charcoal a reddish coating. Soluble in warm muriatic acid, evolving sulphuretted hydrogen. Form. CdS, containing 77.3 pr. ct. cadmium. Local. Bishopton, Renfrewshire, Scotland.

GREENOVITE. *Min.* Cryst. Triclinic (?). H. = 5 — 7. G. = 3.4 — 3.53. Rose-red, with lighter streak; splendid and vitreous on cleavage planes. It consists of titanic acid 74.5, and oxide of manganese 24.8 (*Cacarrié*), and according to Briehaupt is manganesian **SPHENE**. Local. St. Marcel, Piedmont.

GREEN-STONE. See **DIORITE**.

GREEN VITRIOL. *Min.* See **COPPERAS**.

Chem. See **Protosulphate of Iron**.

GRENATITE. See **STAURITIDE**.

GRENGESITE. See **GREEN EARTH**.

GROPPITE. *Min.* Crystalline, foliated; rose-red; subtransparent; brittle; light streak. H. = 3.5. Gr. = 2.73. It yields water in a tube; becomes white on charcoal with partial fusion, and acts like a silicate to the fluxes. Form. $2\text{RO}, \text{SiO}_3 + \text{R}_2\text{O}_3, \text{SiO}_3 + 2\text{HO}$, in which RO is magnesia, lime, potassa and soda, and R_2O_3 alumina and oxide of iron. It has the same formula as prehnite, but with twice as much water. Local. Gropptrop, Sweden.

GRORILITE. See **WAD**.

GROSSULARITE. See **GARNET**.

GUANO. Corrupted from Huano, the Peruvian for dung. The accumulated and altered excretions of certain sea-fowls, deposited on many parts of the coasts of Peru, Bolivia and Africa, in strata, sometimes of many feet thickness. As a manure it is of great value, owing its fertilizing influence to the nitrogen, earthy and alkaline phosphates and other salts which it contains. The variable proportions of these ingredients in the different species occasions

GUANO.

their difference of value. Those which contain the largest per-centage of fertilizing matter (nitrogenous matter and phosphates) are the most valuable. Below are the analyses of several varieties. In addition to the ingredients enumerated, Unger found xanthic oxide, which, from its inequality of distribution through the guano, is supposed to be a diseased product secreted with the excrements of the birds.

The average result of the analyses (by Ure) of genuine guano in reference to its agricultural value, is—

Azotized animal matter (urate of ammonia, &c.) capable of yielding 8 to 16 pr. ct. of ammonia by slow decomposition in the soil.....	50
Water	8 to 11
Phosphate of lime	12 to 25
Phosphate and sulphate of ammonia, ammonia, phosphate of magnesia, containing together from 5 to 9 pts of ammonia	13
Silicious sand	1

2. A brown yellowish guano, by Oellacher:

Sal ammoniac	2.25
Urate of ammonia	12.20
Oxalate do.	17.73
Phosphate do.	6.90
Carbonate do.	0.80
Humate do.	1.06
Phosphate of ammonia and magnesia .	11.63
Phosphate of lime	20.16
Oxalate of do.	1.30
Carbonate of do.	1.65
Chloride of sodium	0.40
Sulphate of potassa.....	4.00
Sulphate of soda	4.92
Waxy matter.....	0.75
Sand.....	1.68
Water	4.31
Undetermined organic matter	8.26

100.00

3. Brown red guano:

	From Liverpool. Bartels.	From Lima. Völkcl.
Sal ammoniac.....	6.500	4.2
Oxalate of ammonia..	13.351	10.6
Urate of ammonia ...	3.244	9.0
Phosphate of ammonia	6.250	6.0
Waxy matter.....	0.600	
Sulphate of potassa ..	4.227	5.5
Sulphate of soda	1.119	3.8
Phosphate of soda....	5.291	
Phosphate of ammonia and magnesia.....	4.196	2.6
Common salt.....	0.100	
Phosphate of lime....	9.940	14.3
Oxalate of lime	16.360	7.0
Alumina	0.104	
Residue insoluble in nitric acid	5.800	4.7
Loss (water, ammonia, undetermined organic matter	22.718	32.3
	100.000	

GUANO.

Chilian Guano.

4. Colquhoun's analysis:

Urate of ammonia, ammoniacal salts, and decomposed animal matter	17.4
Phosphate of lime and magnesia, oxalate of lime	48.1
Fixed alkaline salts	10.8
Stony matters	1.4
Moisture	22.3

100

5. Ure's analysis:

Combustible, organic, and volatile matter, containing $2\frac{1}{2}$ pr. ct. of ammonia	22.5
Water	24
Silica	0.5
Phosphate of lime	53

100

Peruvian Guano.

6. Ure's analysis:

Nitrogenized organic matter, including urate of ammonia	50
Water	11
Phosphate of lime	25
Phosphate of ammonia and magnesia, phosphate of ammonia, oxalate of ditto, containing 4.9 pr. ct. of ammonia	13
Silica	1

100

7. Kersten's analysis of two varieties:

	1.	2.
Combustible matter, of which 3.2 pr. ct. is humic acid; in No. 1, 2.7 uric acid, in No. 2, traces	36.5	35.0
Ammonia	8.6	7.5
Phosphate of lime and magnesia	20.5	22.5
Phosphate, sulphate, and chloride of potassium and sodium	6.5	8.2
Quarzy sand	1.5	2.0
Water	26.0	25.0

100 100

African Guano.

8. Teschemacher's analysis:

Volatile ammonia and salts, as oxalate, phosphate, and humate, with animal matters containing 5 pr. ct. ammonia ..	25
Fixed alkaline salts, as chloride, sulphate and phosphate of potassa	11
Phosphate of lime and magnesia	32
Water	30
Earthy matters	2

100

9. Ure's analysis, sample No. 1:

Saline and organic matter, containing 10 pr. ct. of ammonia	50
Water	21.5
Phosphate of lime and magnesia, also of potassa	26
Silica	1
Sulphate of potassa and chloride of potassium	1.5

100

GUANO.

10. Ure's analysis, sample No. 2:

Combustible animal matter	37
Ammonia, chiefly as phosphate	9.5
Alkaline and earthy phosphates	18.5
Alkaline, chiefly potash salts	6.0
Silica	0.5
Water	28.5

100

11. Kersten's analysis (guano from the island of Ichaboe):

Combustible matter, of which 6.5 pr. ct. is humic acid, with traces of uric acid ..	39.5
Ammonia	9.5
Phosphate of lime and magnesia	17.5
Phosphate, sulphate, and chloride of potassium and sodium	7.3
Quarzy sand	1.3
Water	25.0

100

12. J. Davy's analysis, comparative of the American with the African guano:

	American.	African.
Soluble matters, oxalate, phosphate, and chloride of ammonium, and animal matters	41.2	40.2
Incombustible and insoluble, chiefly phosphate of lime and of magnesia	29	28.2
Incombustible, soluble, chloride, carbonate and sulphate of potassa	2.8	6.4
Combustible, sparingly soluble, chiefly urate of ammonia	19	
Expelled by drying; water and carbonate of ammonia	8	25.2

100 100

Davy found neither urea nor oxalic acid.

13. Francis's analysis:

Volatile salts, as oxalate and carbonate of ammonia, sal ammoniac, and combustible organic matter, containing 5.50 pr. ct. of humic acid, uric acid, and extractive matter, and 9.70 pr. ct. of ammonia	42.59
Water	27.13
Phosphate of lime and magnesia	22.39
Sand	0.81
Alkaline salts, chiefly phosphate, chloride, and a little sulphate of potassa, ..	7.08

100

English Guano.

14. J. Davy's analysis of sample from the Yorkshire coast. It is light brown, and emits an ammoniacal odor when mixed with lime and moistened.

Saline matter (containing, among other matters, nitric, sulphuric and muriatic acids, and lime, potassa, ammonia and magnesia)	10
Organic matter (chiefly vegetable) insoluble in water	24
Phosphate of lime, with a little carbonate of lime and magnesia	21
Sand	39
Hygrometric moisture	6

3 N 2

701

The sample from the Pentland Firth, north coast of Scotland, was in lumps, of a dirty brown color, speckled with white, and yielded an ammoniacal odor when moistened and mixed with lime. It consists, according to J. Davy, of—

Muriate of ammonia, nitrate and sulphate of lime, with a trace of chloride of sodium	4
Vegetable and animal matter, nearly insoluble in water, and destructible by fire	28
Carbonate and phosphate of lime, with traces of magnesia and sulphate of lime	30.6
Sand	29.4
Hygrometric moisture	8.0

Genuine guano is sometimes attempted to be imitated by fraudulent composts, as is shown by the following analysis (*Ure*) of a fictitious article sold as true Peruvian:

Common salt	32.0
Sand	28
Sulphate of iron	5.2
Phosphate of lime	4.0
Organic matter from bad guano (to give smell)	23.3
Moisture	7.5

It will be perceived from the composition of guano, as presented by the above analyses, and inferred from its ready decomposition, and the more or less easy solubility of its important ingredients, that it must prove an invaluable manure, even when sparingly applied to the soil. Practice has preceded theory in this respect, and proved its value, although there can be no doubt that the impulse given by Liebig to chemical agriculture, has induced the more extended employment of guano. On the other hand, the value put upon guano, from its proved practical effects, has tended to confirm the views of Liebig, as set forth in his "Chemistry applied to Agriculture." Some guano may be also used as a source of ammoniacal compounds.

GUARANIN. *Chem.* Identical with **CARFEIN**. Found in the Brazilian *Guarana*, or dried fruit of the *Paulinia sorbilis*.

GUACUM OFFICINALE. *Syn.* *Lignum vitæ*. Tromsdorff's analysis of the wood gave, *Resin* 26.0, *bitter extractive* 0.8, *mucous extractive and vegetable salt of lime* 2.8, *coloring matter* 1.0, and *woody fibre* 69.4. The resin of the bark differs from that of the wood.

Resin exudes naturally from the stem. *Form.* $C_{40}H_{23}O_{10}$. (*Johnston*.) Jahn (*Archiv. der Pharm.* 1843) announces its composition as—

Soft resin, soluble in ether and in ammonia	18.7
Soft resin, easily soluble in ether, but difficultly in ammonia	58.3
Hard resin, soluble in ammonia, but not in ether	11.3
Benzoic acid	traces
Impurities	11.7

Guaiacum resin by distillation yields water, and an oily substance composed of a neutral oil lighter than water and of an acid oil which is heavier, and has its boiling point at 400°.

The *pyroguaiac acid* has a spec. grav. of 1.119, is soluble in alcohol and ether, but very slightly in water; oxidizes on exposure. Its alcoholic solution reduces gold and silver, and causes iron and copper to pass to a lower state of oxidation. (*Sobrero*.) Caustic potassa, but not the alkaline carbonates, dissolve it, and its solution in the former blackens and precipitates carbon upon exposure. Its formula is $C_{15}H_9O_4$. Jahn thinks it identical with benzoic acid; but the later researches of Deville make it a constituent of the resin which he terms *hydruret of guaiacyl*, $C_{14}H_8O_4 + H$. It suffers the same change of color observable in the guaiac resin, which on exposure to air and alkali passes from a light rose-red to deep green. It appears to belong to the same series as tolu balsam. Osann proposes a mixture of recent tincture of guaiacum and salt for detecting feeble electric currents, for, according to Schönbein, it is colored blue by ozone, and also by chlorine. As a test of the perchloride of iron it is extremely sensitive, becoming blue-tinctured even when the proportion added is so small as to give no coloring upon the addition of a tincture of galls.

De Smedt uses hypochlorite of soda to discover the presence of this resin, even to the $\frac{1}{320}$ th part, in those of jalap and scammony, with which it is not unfrequently mixed. The suspected resin dissolved in one-fourth its weight of alcohol of 0.828, gives a green color to a single drop of the hypochlorite if guaiac be present. Subsequently the green precipitate subsides and forms a distinct stratum, while the supernatant liquor retains its primitive color.

The genuineness of guaiacum wood, says Schwacke, is known when a few drops of a solution of chloride of mercury poured over some of its shavings, in a test tube warmed over a spirit lamp, produces a bluish green color. Schacht and Muller have given an essay upon the blue color produced in tincture of guaiacum by various re-agents (*Archiv. der Pharm.* xxxv.); but whether it can be employed to distinguish vegetable from animal albumen is yet uncertain, as it is still to be shown whether the former does not produce the blue color also in its coagulated state, and the latter, likewise, in its soluble form.

GUMS. *Chem., Tech.* The exudations of certain plants, which concrete in transparent or translucent amorphous drops, are of several varieties, but distinct from the resins in being soluble in water and insoluble in alcohol. The general formula is $C_{12}H_{11}O_{11}$, but at 266° they become essentially altered in properties by the loss of one eq. of water. The several species of gums are distinguished by their behavior to water. Some only soften and swell up in that liquid; others again become dissolved and form *mucilages*. From these it is precipitated unaltered by alcohol, and as a white mass, insoluble in water, by subacetate of lead. (The mucilages formed by triturating certain seeds in water, contain silicated, calcareous and nitrogenized matters.) Their proximate principles are *arabin*, *cerasin*, and *bassorin*. Baudrimont considers each of them identical, and that the apparent difference between them is not owing to

any species of polymorphism, but to the presence of foreign matters, which mix in with them during desiccation and vary their properties. The same chemist attributes a general basis to all gums, and calls it *mucose*. It is particularly insoluble in water, and is the same substance generated in the viscous fermentation of sugar. Liebig divides them into gums soluble in cold water, arabin, mucilage; and gums which only swell up to a jelly, tragacanth, cerasin, pectin. Like sugar of milk, they yield mucic acid when acted upon by nitric acid. Gottlieb (*Ann. der Chem. und Pharm.* lii.) obtained formic and acetic acids, and also the metacetic acid, by the action of concentrated potassa solution upon gum; binoxalate of potassa being also a simultaneous product.

Arabin. Form. $C_{12}H_{11}O_{11}$, the same as that of cane sugar. It constitutes the principal part of gum arabic, senegal, and of other gums, and is found in almost all plants, as well as in nearly all parts of plants. It dissolves in water, which becomes mucilaginous in proportion to the quantity dissolved. Some chemists hold that its particles, instead of being dissolved, are merely suspended in water, and not being capable of suspension by alcohol, are precipitated by it. But this precipitation will not occur unless the alcohol be of high proof, for arabin or gum is retained by dilute spirits. Silicate of potassa, acetate of lead, and the subsalts of iron also precipitate it from its apparent solution. Ether and the oils are without influence in dissolving it. By the action of nitric acid it passes into mucic, and finally into oxalic acid. Sulphuric acid, at a temperature near boiling, transforms it into dextrin and glucose. Its solution in boiling water is much less viscous than when made with cold water. Their circular polarizing power is left. Arabin is not susceptible of the alcoholic fermentation, but when dissolved and exposed it acquires an acid reaction. According to Vauquelin and Simonin, chlorine gas produces citric acid in a solution of gum, but their result has not been confirmed.

The composition of arabin dried at 212° , $C_{12}H_{11}O_{11}$. According to Guerin and Mulder, gum senegal at 266° loses an eq. water, becoming $C_{12}H_{10}O_{10}$, which formula it shows in its compound with litharge. When the lead compound is dried at 356° its formula is $C_{12}H_9O_9$ (Peligot), but it is altered in its nature. Mulder.

Mucilage. The gum obtained from carrageen, flaxseed, quince seed, althea root, symphitum and salep, is soluble in water, and precipitates with oxide of lead. Their compound with oxide of lead points to the formula $C_{12}H_8O_{10}$. (Mulder.) When heated it behaves like arabin.

Bassorin, constituting a large portion of gum tragacanth and other gums, is less transparent than arabin, difficultly pulverizable, softens and swells in water, and forms a transparent jelly. The pure alkalies and silicate of potassa dissolve it completely. In composition it is identical with arabin, and, like it, is transformed by digestion with dilute sulphuric acid into grape sugar and cellulose. Nitric acid converts it into mucic acid and ultimately into oxalic acid.

Guibourt considers tragacanth entirely different in composition and chemical and physical properties from gum arabic, and as consisting of an organized gelatinous matter, and that its insoluble portion is not bassorin, but a mixture of starch and lignin.

Adragantin may be modified arabin, as it only differs from it in being unaltered by silicate of potassa and perchloride of iron, and also by the peculiar opaque mucous mass which its precipitate by alcohol forms.

Mulder's analysis of the compound of bassorin and lead gives nearly $C_{12}H_8O_{10}$. Mulder's analysis of pectic acid gives the same formula, and they all appear also to belong to the same class of bodies from other analogous properties, but different from arabin in an excess of oxygen over hydrogen. See PECTIN.

By the viscous fermentation of beet roots, &c. a mucilaginous substance is produced, which, according to Kircher, has the same composition as arabin.

Cerasin is the chief proximate principle of the gums yielded by the different species of *Prunus*. It is insoluble in water and allied to bassorin, but by boiling conducts itself to that liquid similarly as arabin, like which it is also affected by dilute sulphuric and nitric acids. The chloride of tin precipitates it, but this property does not belong to the silicate of potassa, the subsalts of iron and the nitrate of mercury. Guerin-Vary.

Calendulin, *Phyteumacolla* and *Pseudotoxin* seem to be of the same character as the above mucilaginous substances. It is evident that the chemical nature of the several gums remains to be investigated. For the gum from torrefied starch, see *BRITISH GUM*; for those from the decomposition of starch spontaneously or by sulphuric acid, see *DEXTRIN* and *STARCH*. Until the composition and properties of the constituents of natural gums are well known, investigations of the latter cannot be depended on.

Gum Arabic is the gum of the *Acacia vera*, *arabica*, *tortilis*, *senegal*, &c. The purest kind is colorless, or light yellow, transparent, somewhat brittle. When darker colored and tougher, it passes into *Gum Senegal*, which appears to contain a larger portion of insoluble or mucous gum (bassorin?). The dry gum heated in a water-bath loses about 16 pr. ct. water, besides which it contains 3 pr. ct. salts. A solution of gum prevents the precipitation of fine powders, and hence one of its applications for inks, mucilages. Its clamminess when moist, and firmness when dry, gives rise to its application for cementing or pasting paper and other light articles which are not to be exposed to moisture.

Gum Tragacanth, the product of several species of *Astragalus*, expands through a large quantity of water, and being tough when dry, forms a superior paste to gum arabic. Between these two extremes of perfectly soluble gum arabic and the merely swelling tragacanth, there appear to be various mixtures of the two gums obtained from different plants, such as cherry-tree gum, &c.

GUM ELASTIC. See *CAOUTCHOUC*.

GUM RESINS. *Tech.* Natural compounds

GUN-COTTON.

of gum, resin, and essential oil, obtained by puncturing certain plants. The milky exudations upon exposure to air become concrete and changed in aspect.

The emulsion which they form with water is owing to the solution of the gum, and the consequent suspension of the other components in the mucilage. Dilute alcohol is a better solvent of them than spirit of greater strength, because it takes up both gum and resin. In dilute alkalies they are completely soluble.

Gum resins are always more or less mixed with foreign impurities, of which it is often desirous to rid them. Lamothe proposes the following economical method: Macerate 1 pt. of gum resin in 4 pts. distilled water for a day, frequently agitating with a wooden spatula, and at the end of that time heat the mixture for a few minutes to 158° or 168°, and strain through a linen cloth. Press the residue gently, and treat it again as before to a fourth digestion, with 2 pts. of distilled water each time. The remaining pitchy magma must be exposed to a gentle heat in half a part of essence of turpentine and as much distilled water: the former dissolves the resin, the latter the gummy portion. Strain with pressure. If the residue is not entirely exhausted, again place it over the fire with a fresh quantity of essential oil and water. Mix all the liquids, and evaporate over a water-bath, during constant stirring, until the dissipation of the water.

The peculiar character of the resins and gums in the gum-resins have not been investigated, excepting in a few instances. The principal gum-resins are ammoniac, asafetida, bdellium, euphorbium, galbanum, gamboge, myrrh, olibanum, opium and scammony. See these articles.

GUN-COTTON. See **COTTON.**

GUNPOWDER. *Tech.* A mixture of nitre, sulphur, and charcoal, which deflagrates violently when touched by a spark. The materials are required in a state of great purity and finely pulverized. Saltpeter is freed from all chloride (common salt), by crystallizing it in fine powder, and washing with a saturated solution of pure saltpeter. This crystalline flour may be employed without farther grinding, but if it is to be stored up, it should be fused and cast into blocks. The flowers of sulphur are apt to contain sulphuric acid, and hence pure roll sulphur is pulverized. The best charcoal is made from branches of willow, hazel, vine, &c., 1 to 2 inches thick, in iron cylinders, care being taken to avoid the return and carbonization of tarry vapors. Particles of sand remaining with the charcoal might endanger explosion. The charcoal is pulverized in revolving drums or cylinders, with longitudinal ledges, by means of bronze or zinc bullets; for example, 36 lbs. of charcoal are put into the drum with 3 cwt. of bullets, and revolved for 12 hours, at 30 revolutions per minute; 30 lbs. roll sulphur is then introduced, and pulverized and mixed with the charcoal at the same time. The flap of the drum is replaced by a sieve, and by revolving, the mixed powder falls into the trough below. This is then mixed with fine saltpeter in an-

GUNPOWDER.

other drum with tin bullets. The whole mixture being moistened with $\frac{1}{10}$ water, is spread $\frac{1}{8}$ inch thick on a copper surface, a moist cloth laid over it, another layer of paste, and so on until of sufficient thickness to go under the hydraulic press, where the layers are reduced to $\frac{1}{2}$ their former thickness. Stamping mills and chasers are also used both for pulverizing and mixing.

The cake is next granulated or corned. Lumps could not be used, from the difficulty of regulating a charge, and on other grounds. Dust powder would be apt to separate by carriage in kegs, the heavier saltpeter and sulphur sinking to the bottom. Grain powder is more advantageous on other accounts. The ignition of a lump can only be progressive; that of dust, less violent, because the particles lie too close; while in grain it ignites many grains or points simultaneously; moreover, grains are less attractive of moisture than dust. Fine grained powder ignites more explosively than coarse, and hence the former is used for sporting, the latter for cannon. The cake is broken by crushing it into coarse sand, which by sifting is separated into dust, grain of proper size, and those too large. The sieves are made of brass wire, hair, perforated parchment, leather, &c.

The grain is usually polished or glazed by being introduced into revolving barrels, very slightly moistened, made to revolve slowly at first, then faster, and finally more slowly to cool off the powder. It is then dried in layers in the open air, in sun or shade, or still better by currents of warm, dry air, in apartments.

Composition. The following table presents the composition of various kinds of gunpowder.

Kind of Powder.	To 100 pts. Nitre.	
	Charcoal.	Sulphur.
Best composition.....	17.76	15.86
Prussian, military	17.8	15.3
American and French, military	16.6	16.6
Austrian, musket	17.3	15.0
English (Waltham)	18.0	13.3
“ (Dartford)	15.6	9.8
Italian, military	15.8	15.8
Hessian, cannon	14.4	20.4
Russian, “	25.0	16.6
Dutch, “	22.9	20.0
Chinese, military.....	37.4	25.2
Blasting	31.0	23.0
Italian, sporting	24.8	11.7
French, “	17.5	12.5
Champy	24.7	6.3

The proportions may evidently be varied within wide limits, and they constitute so many kinds of powder, according to the object in view. The nature of the bodies resulting from the explosion enables us to estimate with some precision the force of powder, but experience has led to similar and more reliable results. When a mixture of 4 pts. nitre (1 equiv.) and 1 pt. charcoal (4 equivs.) are deflagrated, the combustion is vivid from the rapid decomposition of the nitric acid in the saltpeter, by the formation of carbonic acid and oxide, and liberation of nitrogen, KO, NO,

+ $C_4 = KO, CO_2 + N + 3 CO$. Since carbon combines more slowly and progressively with oxygen, and part of the carbonic acid remains with the potassa, and since carbon does not decompose the potassa, the action is less violent than where sulphur is employed. Thus when a mixture of 3 pts. nitre, 1 pt. carbonate of potassa, and 1 pt. sulphur, are gently heated, the sulphur begins to fuse, and a violent explosion ensues, which would endanger the strongest vessels, because the gaseous matter, nitrogen, and carbonic and sulphurous acids, are instantly and not progressively liberated; sulphate of potassa, with some sulphuret of potassium, remains. While therefore a powder, made with a large excess of sulphur, would explode violently and dangerously, and while the deflagration of charcoal is too slow, a proper mixture of the two combustibles with nitre produces the best explosive compound. The reason why a violently explosive body, like that above mentioned, or any fulminating substance, cannot be employed as gunpowder, lies in the necessity of overcoming the inertia of a body. Suppose a bullet to be rammed into a gun above the powder, and the latter to be then ignited, the gases evolved must first overcome the inertia of the ball, which for the first moment of time acts as resistingly as the sides of the barrel. If then the powder be fulminating, nearly all the gas is generated at this moment of time, and the consequence must be a bursting of the barrel, unless it be of inordinate strength. If it be common gunpowder, its ignition is progressive, so that the small amount of gas generated in the first instant exerts itself to propel the ball, whose velocity is accelerated by the continued evolution of gas through the whole length of the tube.

The composition of the best powder in the above is precisely $KO, NO_5 + C_3 + S$, which by explosion is resolved into $KS + N + 3 CO_2$. 100 pts. by weight yield 59 pts. by weight of gas, nitrogen and carbonic acid, or 1 vol. yields 300 vols. gas. A powder composed of $KO, NO_5 + C_6 + S$, somewhat similar to the Chinese powder in the above table (or 35.5 charcoal and 15.8 sulphur to 100 nitre), is resolved into $KS + N + 6 CO$. 100 pts. yield 64 pts. gas (nitrogen and carbonic oxide), or 1 vol. yields 450 vols. gas. It would seem therefore that the latter composition were the better; but the heat developed where carbonic acid is produced is twice as great as where carbonic oxide results, and therefore the expansive force of the former is much greater than that of the latter. For the 300 vols. of the first heated to 2200° become 1600, while the 450 of the last when heated to 1100° become only 1400. This expansive force of the former more than counterbalances the greater amount of gas and less cost of the latter. Between these extremes, we have various compositions, by which mixtures of carbonic oxide and acid result, and a different sulphuret of potassium. Thus the blasting powder of the above table is $KO, NO_5 + C_4 + S_2$, and yields $KS_2 + N + 2 CO_2 + 2 CO$. Such powder with excess of sulphur should

not be used for fire-arms, as the bisulphuret of potassium remaining would form, besides sulphate of potassa, some free sulphuric acid by oxidation, whereby the metal would be corroded. In the best powder, and in all those with less sulphur, the simple sulphuret of potassium can only oxidize to neutral sulphate of potassa. But powder with excess of sulphur may be used for blasting rocks, and presents the advantage of greater explosiveness. The more powerful action of gun-cotton will probably cause it to be substituted for gunpowder, in blasting, if not for other applications. See COTTON, (GUN.)

GURJUN. A thin balsam, well known in the Indian bazaars, analogous in physical, chemical, and therapeutic properties to copaiba balsam. (*O'Shaugnessy.*) It is the product of a tree, the *Dipterocarpus levis*. As found in commerce, it is a brown, semitransparent, oily liquid, of spec. grav. 0.962, totally insoluble in water, difficultly in ether, but readily in hot alcohol of 0.835. By distillation, water is eliminated, and afterwards a crystalline substance covers the upper part of the still, while an essential oil runs over, and a residuum remains.

Essential oil. Freed from water by prolonged contact with dry chloride of calcium and redistillation, it is nearly colorless, boils at 240° , and has a spec. grav. of 0.934. Is soluble in alcohol, ether, naphtha and the oils, and dissolves caoutchouc, copal, valerian resin, and solid gluten. Potassium and sodium are preserved unaltered in it, and with undiminished lustre. Its odor resembles that of oil of copaiba.

The resin remaining after the distillation of the oil is light brown, faintly acrid and easily fusible. It is separable into two resins by absolute alcohol, of which the insoluble *Peta* resin dissolves in alcohol of 0.835. Both have acid properties, and are analogous to the copaiba acid resins. Like one of them, the gurjun *Alpha* resin forms a saline compound with magnesia, which dissolves in a mixture of the beta resin and essential oil. (*Chem. Gaz.* 1843.)

GURHOFFITE. See BITTER SPAR.

GUTTA PERCHA. The Malayan name for the concrete juice of a tree, a native of Malacca, Borneo, and their vicinities. The botanical name of the tree is unknown. Gutta percha is a variety of caoutchouc, but when crude, differs from it in several particulars. It is of a dirty white color, very tenacious, non-elastic, and nearly as hard as wood. According to Dr. McLagan's analyses, it is a modification of caoutchouc, as it yields similar products by distillation, and, like it, is soluble in caoutchicine, coal naphtha, and ether. Heat develops its most distinctive peculiarity. Water at 110° does not affect it, but at 145° and upwards it softens and becomes so pliant that it can be moulded in forms or rolled in sheets. Its caoutchouc elasticity in the soft state decreases as it hardens again, and at last, when the gutta has acquired its original rigidity, has entirely disappeared. It is capable of alternate hardening and softening any number of times

without change of property. It is ductile to a certain extent, and so tenacious that a piece of $\frac{1}{8}$ inch thickness, when cold, will suspend upwards of 40 lbs. without breaking. Its pliability in a soft state, and other advantageous properties, render it a useful substitute for India rubber for many purposes. The Malays use it as material for many domestic implements. (*Ed. Phil. Jour.*) See Kent in *Amer. Jour.* Sept. 1848; Vogel in *Chem. Gaz.* vi. 236; and Whishaw, vi. 352.

GUYAQUILLITE. *Min.* A mineral resin, of pale-yellow color; $G. = 1.092$. Begins to fuse at 157° , is perfectly fluid at 212° , and forms empyreumatic oils by distillation. Its solution in alcohol has a very bitter taste; soluble in dilute potassa, and reprecipitable by acids; soluble in oil of vitriol, and reprecipitable by water. It combines with bases. Form. $C_{20}H_{13}O_3$. See BERENGELITE, MIDDLETONITE, RETINITE.

GYMNITE. *Min.* It occurs near Baltimore, and, according to Thomson, its composition is $2 MgO, SiO_2 + 3 HO$.

GYPSUM. *Min.* Syn. Alabaster, Selenite, Sulphate of Lime, Plaster of Paris; $\Gamma\acute{\epsilon}\lambda\acute{\alpha}\varsigma$. Cryst. Oblique Rhombic; cleavage very perfect parallel to second end-plane; two others imperfect; Pl. IX. figs. 30, 31. It is sometimes compounded on a plane parallel to a front edge, and gives an arrow-shaped form. It also occurs lamellar, fibrous, granular and nearly compact (Plaster). $H. = 1.5 - 2$. $G. = 2.31 - 2.36$. Color generally white, sometimes reddish, yellowish blue; lustre of main cleavage pearly, otherwise vitreous; transparent, nearly opaque.

Chem. Rel. Yields water in a tube; on charcoal becomes white, opaque, exfoliates, and fuses to a white enamel with alkaline reaction, and is partly reduced to a sulphuret; fuses readily to a clear bead, which enamels on cooling. Form. $CaO, SO_2 + 2 HO$. See further *Sulphate of lime* under CALCIUM.

Local. When crystallized, it is sometimes termed Selenite; when fine-grained and translucent, Alabaster. Massive gypsum, or plaster of Paris, occurs in extensive deposits in secondary and tertiary deposits, and is most frequently associated with rock salt or salines. Fine specimens occur in many localities in Europe. In the U. S., large beds occur in New York, Ohio, Illinois, Virginia, Tennessee, and Arkansas. Fine specimens are found at Lockport, Camillus, Manlius, N. Y.; Poland and Canfield, Ohio; on the St. Mary's and Patuxent, Md. Beautifully curved fibrous efflorescences ornament some of the farthest chambers in the Mammoth Cave, Kentucky. Heavy beds occur in Nova Scotia.

Use. Gypsum is a valuable mineral for application in agriculture; for taking plaster casts of objects of ornament and utility; as an addition to mortars and cements; and in making artificial marbles. It is of great value for moulds in stereotyping, and obtaining fine metallic castings generally; for moulds in porcelain, and nearly all the clay manufactures. See *Sulphate of lime* under CALCIUM.

GYRASOL. See OPAL.

H.

HAIDINGERITE. See BERTHIERITE.

HAIR. Its organic constituents are margarin, olein, a brown matter, soluble in water, lactate of ammonia, and margaric acid.

Chlorides of sodium and potassium, peroxide of iron, sulphates of lime and magnesia, and phosphate of lime and silica are the inorganic components. The proportion of soluble and insoluble inorganic parts varies in hairs even of the same color.

According to Van Lear, hair consists of a gelatinous tissue, the formula of which is $C_{13}H_{10}N_2O_5$, and of bi-sulphuret of protein, $C_{40}H_{31}N_5O_{12}S_2$. The effect of several of the metallic salts upon the color of the hair is due to the large amount of sulphur which it contains. After extracting the unessential constituents with water, alcohol, and ether, and passing chlorine through it in water, a chlorite of protein is formed. By dissolving the latter in ammonia, and washing the evaporated residue with alcohol, it forms tritoxo-protein. By dissolving pure hair in caustic potassa, and reprecipitating with excess of acid, a yellow bioxy-protein is obtained.

HAIR PYRITES. *Min.* Syn. Capillary P.; Haarkies; Sulphuret of Nickel. Cryst. Hexagonal, with rhombic cleavage; generally in fine hair-like form. $H. = 3$. $G. = 5.278$. Light yellow; metallic; opaque; brittle. It gives sulphurous acid by roasting; and forms, on charcoal, a malleable, magnetic mass, which behaves to the fluxes like nickel; soluble in nitro-muriatic acid. Form. NiS . *Local.* Johanngeorgenstadt, Andreasberg, and Cornwall.

HALLITE. See ALUMINITE.

HALLOYSITE. *Min.* Syn. Halloylite, Tuisite, Lenzinite, Severite, Pholerite, Nontronite, Pinguite. Amorphous, earthy, soft, unctuous, white, variously tinted. They yield water in a closed tube; some are fusible, and others not; they are wholly decomposed by oil of vitriol. They are all hydrous silicates of alumina, and are probably mixtures of different hydrosilicates. In nontronite and pinguite, the alumina appears to be replaced by oxide of iron. They contain 37 to 46 pr. ct. silica, 32 to 40 alumina, and 15 to 25 water. See ALLOPHANE, BOLE, &c.

HALOGENS. A term derived from *ἅλς, salt*, and applied by Berzelius to those elementary bodies whose union with the metals produce haloid salts. Chlorine, iodine, bromine, and fluorine are the simple halogens, but as cyanogen, by analogy, behaves similarly, it is styled a compound halogen body.

HALOID SALTS. Syn. Halogen Salts. Compounds of a metal and a halogen body. The term is from *ἅλς, salt*, and *ειδής, form*, because the principal group consists mostly of binary compounds, one or both of which are analogous in composition to common salt. The single and double chlorides, iodides, cyanides, and the like, are of the haloid class of salts. They differ in constitution from the *oxysalts*, and hence are sometimes styled salts

HARMALIN.

of the *hydracids*. In the double haloids, the bases are usually the electro-positive, and the acids the electro-negative metals. For the action of water, see Rose in *Chem. Gaz.*, vol. i. 118, and *Pogg. Ann.* iv. 533.

HARMALIN. Form. $C_{24}H_{13}N_2O$, or $C_{27}H_{14}N_2O_2$. (*Fritzsche*). Exists in the seeds of the *Peganum harmala*, which are abundant in Russia. It crystallizes in yellowish brown transparent crystals, and is much more soluble in alcohol than in ether or water. Its salts (*Chem. Gaz.* v. 348) are yellow, unless it has been previously oxidized, then they are of a brilliant red. Being of easy application, its coloring matter is coming into use as a dye-stuff.

Leucoharmin. Obtained by heating chromate of harmalin, extracting by alcohol, and evaporating, to form colorless prismatic crystals; or by treating harmalin with a small dose of nitric acid. The *harmin* of *Fritzsche*, which is probably identical, is described at p. 477, *Chem. Gaz.* vol. v.

Chrysoharmin. Add alcohol to an aqueous solution of sulphate of harmalin, and then, gradually, strong nitric acid. The precipitate, or salt, of the new base, washed with alcohol, dissolved in water, and precipitated, is of a golden-yellow color.

Harnula, or **Porphyharmin**. Extracted from the seeds, by infusing them with a little alcohol for some time, pouring off the liquid, treating the seeds with acidulated water, and precipitating by ammonia, when it falls of a brilliant red color. See further *Chem. Gaz.* v. 348.

HARMOTOME. *Min.* Syn. Baryt-harmotome; Andreolite; Andreasbergolite; Ercinite. *Ger.* Kreuzstein. Lime-harmotome; Phillip-site; Gismondine; Aricite; Zeagonite; Morvenite. Cryst. Right rhombic. $H. = 4 - 4.5$. $G. = 2 - 2.4$. White, of various shades; vitreous; translucent, opaque; brittle, with uneven fracture. Baryt-H. fuses with difficulty, and without effervescence; the lime harmotome swells up; both yield water in a tube. Both are soluble in muriatic acid, when in fine powder. From many analyses of both varieties, they appear to be the same, and their general formula $3RO, 2SiO_3 + 4(Al_2O_3, 2SiO_3) + 18HO$; in which RO is baryta, lime, potassa, and soda.

HAUYNE.

HARRINGTONITE. See **BREVICITE** and **MESOTYPE**.

HARTIN. *Min.* A white crystalline resin, obtained from an ether-extract of brown coal; inodorous and tasteless; most soluble in distilled petroleum, begins to fuse and decompose at 446° . Form. $C_{20}H_2O_2$. Another resin separated from hartin, consists of several other resins, of which the α resin is $C_{42}H_{29}O_5$, the β resin $C_{32}H_{21}O_5$. Two distinct resins occur in the same brown coal, one of which has the composition and nearly all the properties of hartin, the other is hartite.

HARTITE. *Min.* Cryst. Oblique Rhombic. $H. = 1$. $G. = 1.046$. White, translucent, greasy. Fuses at 168° , and distils over scarcely changed; is very soluble in ether. Form. C_6H_5 , and appears to be isomeric with tekoretin.

HATCHETIN. Mineral Tallow. Crystalline, soft as wax; $G. = 0.916$. White, transparent, greasy. Fuses at 115° , distils over unchanged; dissolves slightly in hot alcohol, much more in hot ether. Form. CH , which is the same as ozokerite.

HAUSSMANNITE. *Min.* Syn. Black Manganese; Scharfmanganerz. Cryst. Quadratic; cleavage parallel to main end-plane; also granular. $H. = 5 - 5.5$. $G. = 4.72$. Brownish black, submetallic, opaque; uneven fracture, and brown streak. Oil of vitriol colors the powder red; soluble in muriatic acid, with evolution of a little chlorine; behaves to the fluxes like oxide of manganese. Form. MnO, Mn_2O_3 , corresponding to magnetic iron, with which it appears strange that it is not isomorphous. *Local.* Ilmenau, in Thuringen; Framont, in Elsass; and Lebanon, in Pennsylvania.

HAUYNE. *Min.* Syn. Nosean, Itnerite, Spinellan, Lapis Lazuli, Ultramarine, Lazurstein. Cryst. Regular 12-hedron. $H. = 5.5 - 6$. $G. = 2.5 - 3.3$. Brilliant azure-blue, rarely green; vitreous; transparent, opaque; fracture uneven. Fuses with difficulty to a white blebby glass. Decomposed by muriatic acid, the silica gelatinizing.

Analysis. 1 and 2 by Bergmann; 4 by L. Gmelin; 3, 5, 6, and 7 by Varrentrapp. 1, 2, and 3, Nosean, from Laacher lake; 4, Hauyne, from Marino; and 5, from Niedermendig; 6, Lapis Lazuli; and 7, Artificial Ultramarine.

	1.	2.	3.	4.	5.	6.	7.
Silica	38.50	37.00	35.99	35.48	35.01	45.50	45.60
Sulphuric acid.....	8.16	11.56	9.17	12.39	12.60	5.89	3.83
Alumina	29.25	27.50	32.57	18.87	27.41	31.76	23.30
Potassa.....	—	—	—	15.45	—	—	1.75
Soda	16.56	12.24	17.84	—	9.12	9.09	21.48
Lime.....	1.14	8.14	1.11	12.00	12.55	3.52	0.02
Oxide of iron.....	1.50	1.15	0.04	1.16	0.17	0.86	1.06
Ox. manganese.....	1.00	0.50	—	—	—	—	—
Chlorine	—	—	0.65	—	0.58	0.42	trace
Sulphur.....(HS)	3.00	1.50	—	3.45	.24	0.95	1.69
Water.....	—	—	1.85	—	.62	0.12	—
	99.01	99.59	99.22	98.81	98.30	98.11	98.73

It is exceedingly difficult to establish a formula, although the above minerals doubtless agree in composition. There is a large proportion of $\frac{1}{3}$ silicate of alumina, with $\frac{1}{3}$ or $\frac{2}{3}$ silicate of lime or alkali, together with sul-

phate and muriate of alkali, which is chiefly soda.

Local, &c. Hauyne occurs in Vesuvian lavas, at the Laacher lake, and Niedermendig, near Andernach on the Rhine. Lapis-lazuli

is found in granite and altered limestones, and is brought from China, Siberia, Persia, &c. For its use as a pigment, see **ULTRAMARINE**.

HAYDENITE. *Min.* Cryst. Oblique Rhombic. $H.=3$. $G.=2.136-2.265$. Brownish, greenish, or wine-yellow; vitreous, bright; translucent, transparent; brittle. In a tube it gives off water and empyreumatic odor; fuses with difficulty. Partially decomposed by sulphuric acid, depositing crystals of alum. (*Silliman*.) From *Silliman's* analysis, if the iron be protoxide, the formula is either $3(CaO, SiO_2) + Al_2O_3, 2SiO_2 + 4HO$, or it is $3CaO, 2SiO_2 + Al_2O_3, 3SiO_2 + 4HO$, the former of which is more likely; or if the iron be peroxide, the form is nearly $2(CaO, SiO_2) + Al_2O_3, 3SiO_2 + 4HO$. It evidently is a zeolitic mineral. *Local.* Jones' falls, near Baltimore.

HAYESINE. *Min.* See **BOROCALCITE**. By comparing the formula there given with that of hydroboracite, as suggested by Berzelius, the two minerals are the same, a portion of lime in the former being replaced by magnesia in the latter. But several analyses of the latter seem to prove it to be $3RO, 4BO_3$. And since Hayes' analysis will not admit of the latter formula, the minerals are different species.

HEAT. *Chem. Syn.* Caloric. *Ger.* Wärme, Wärmestoff, Hitze. *Fr.* Chaleur, Calorique. Heat is indifferently used to signify the sensation produced by touching a hot body, and the cause of that sensation. The latter is sometimes termed *caloric*.

Heat may be viewed as the vibrations of an ethereal medium, or as a highly elastic, invisible, imponderable, self-repulsive fluid, existing in all matter, as far as we know.

1. *Radiation.* A hot body throws out rays of heat in every direction through a void, through gases, and through many liquids and solids, its intensity being inversely at the square of the distance from the heated centre. This heat is termed *radiant heat*. It passes freely through gases, without affecting their temperature; but when it meets with a solid or liquid it is more or less retained, each solid and liquid seeming to have a specific power in this respect. Thus, while a glass mirror or lens concentrates the rays of sun-light, it will not those of a red-hot iron ball, because so much of the heat is absorbed in the latter case. In like manner, a heated body seems to have a specific power of radiation, depending on the nature of the surface. The rays of heat are refrangible; the hotter the radiant body, the more refrangible are the rays.

The following table of the radiant power of surfaces is by Leslie:

Lampblack	100	Red lead	80
Writing paper ...	98	Graphite	75
Rosin	96	Tarnished lead...	45
Sealing wax	95	Clean lead	19
Crown glass	90	Polished iron....	15
Ice	85	Other pol. metals..	12

Diathermous bodies are those which allow rays of heat to pass through them, such as salts, water, and even some nearly opaque bodies, as black glass. Of 100 rays from the flame of an Argand lamp, the following table

shows the number transmitted by the bodies named. *Melloni*.

Name.	Color.	No. of rays.
Rock salt	colorless	92
Flint-glass	"	67
Bisulphur. carbon	"	63
Calc. spar and quartz	"	62
Smoky topaz	brown	57
Crown glass	colorless	49
Chalcedony	white	35
Glass	violet	34
"	red	33
Bichromate potassa	orange	33
Spirits terpentine	colorless	31
Fat oil	"	30
Aqua marine	green	29
Borax, translucent	colorless	28
Turmaline	green	27
Copaiva balsam	brown	26
Adular, translucent	colorless	24
Glass	green	23
"	yellow	22
"	blue	21
Ether	colorless	21
Gypsum	"	20
Oil of vitriol	"	17
Glass, opaque	black	16
Nitric and citric acids, and } alcohol	colorless	15
Alum	"	12
Water	"	11

The same body transmits different quantities of heat from different sources, as shown by the following table by *Melloni*:

Name.	Locatelli Lamp.	Red-hot Platin'm	Copper at 734°.	Copper at 212°.
Free radiation.	100	100	100	100
Rock salt	92	92	92	92
Fluor spar	78	69	42	33
Calc. spar	39	28	6	0
Plate glass	39	24	6	0
Agate	23	11	2	0
Gypsum	14	5	0	0
Alum	9	2	0	0
Ice	6	0	0	0

The transmitted rays are then nearly all again transmitted by the same or other substances.

2. *Conduction.* When heat is absorbed by the surface of a solid body, it spreads or travels slowly through it, the rapidity varying with the nature of the body, as shown in the following table by *Despretz*:

Gold	1000	Tin	304
Silver	973	Lead	180
Copper	898	Marble	24
Platinum	381	Porcelain	12
Iron	374	Brick	11
Zinc	363		

Porous bodies conduct badly, especially organic bodies.

Liquids conduct heat more slowly than solids, so that it is next to impossible to heat a liquid from above. When the heat is applied

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below, the heated part expands, becomes specifically lighter, and rises, while a colder stratum flows in to supply its place, and rises in like manner. Thus, a liquid is heated by *circulation* or *convection*. It is almost impossible to determine whether gases do or do not conduct heat.

3. *Expansion.* See EXPANSION, THERMOMETER.

4. *Specific heat.* If the same heat be applied to two different bodies, they will absorb different quantities, or one will require a longer time to show the same sensible heat. This amount of heat is termed *specific heat, capacity for heat*, when equal weights, and *relative heat*, when equal volumes are compared. The methods of determining the specific heats of bodies are various; by ascertaining how many degrees of heat are imparted to an equal amount of water by equal weights of bodies equally heated; or how much ice at 32° they melt; or how long they are in cooling; or by mixing them together at known temperatures, and observing the resulting heat. See table of EQUIVALENTS, for the specific heat of the elements. The specific heat seems to increase with the temperature, as the following table shows, the 1st column being the specific heat from 32° to 212°, and the 2d that from 32° to 572°.

Glass.....	0.1770	0.1900
Iron.....	0.1098	0.1218
Copper.....	0.0949	0.1013
Zinc.....	0.0927	0.1015
Silver.....	0.0557	0.0611
Platinum.....	0.0355	0.0397
Mercury.....	0.0330	0.0350

Dulong pointed out a relation between the specific heats and equivalents of bodies. If the number 3.1 be divided by the specific heat, as in the following table, the quotient is nearly the equivalent, or stands in a simple ratio to it. The first column contains the substances, the 2d their specific heats, the 3d the quotient, $3.1 \div \text{sp. H.}$, the 4th the assumed equivalents.

Substance.	Specific Heat.	$\frac{3.1}{\text{Sp. H.}}$	Real Equiv.
Lead.....	0.031	100.0	103.6
Tin.....	0.056	55.4	57.9
Zinc.....	0.095	32.6	32.3
Bismuth.....	0.029	106.9	213.0
Iodine.....	0.054	57.4	126.3
Silver.....	0.057	54.4	108.0
Phosphorus.....	0.188	16.5	31.4
Carbon.....	0.257	12.1	6.0

The same relation is found to exist among compound bodies, although each particular class of bodies seems to require a special number instead of 3.1. Thus, for some carbonates the number is 10.4, for certain sulphates it is 12.4, and for some oxides it is 5.4. The 3d column in the following table is the quotient of those numbers by the specific heats of the substances named.

By multiplying the specific heat by the atomic weight, the number 3.1 or 3.2 is obtained for most elements, which number may

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Substance.	Specific Heat.		Real Equiv.
Carbonate of lime....	0.2044	50.9	50.0
“ iron....	0.1819	57.2	58.0
“ zinc....	0.1712	60.7	62.5
Bitter spar.....	0.2161	48.1	46.7
Sulphate of baryta...	0.1068	116.1	116.6
“ strontia...	0.1300	95.4	92.0
“ lime....	0.1854	66.8	68.0
Magnesia.....	0.276	19.6	20.7
Oxide of mercury....	0.049	110.2	108.0
“ zinc.....	0.132	40.9	40.5
“ copper.....	0.137	39.4	39.7

be termed the normal capacity for heat of the elementary atoms, but in oxygen it is 1.6, or $\frac{1}{2}$ the normal capacity, although in some compounds it enters with $\frac{3}{2}$ the normal, or 2.4. Chlorine, bromine, iodine, phosphorus, arsenic, antimony, silver, and gold, have double the normal, or 6.4. Carbon, sulphur, and nitrogen seem to have different capacities, according to the compounds they form.

It appears that in general the capacity of compound atoms is the sum of the capacities of their elements. Thus, the capacity of copper being .0951, its atomic capacity is 3.01, (*i. e.* its equiv. $31.7 \times$ its sp. heat.) Hence, the atomic capacity of the red oxide should be $2\text{Cu} + \text{O}$, $1.6 = 7.6$; now the observed capacity of this oxide is 0.1173, and being $\times$ its equiv., the resulting atomic capacity is 7.68. So the observed atomic capacity of ice is 6.48, its calculated 6.4. Of the oxides chrome, iron, and bismuth, observed 13—14.4, calculated 14. Of oxide of lead, Pb , $3.26 + \text{oxygen } 2.4 = 5.66$, the observed is 5.69; of dry sulphuric acid, S , $3.2 + 3\text{O}$, $(1.6 \times 3) 4.8 = 8.0$; and of sulphate of lead $5.69 + 8$, = 13.69, the observed of which is 12.87. See full tables, in *Gmelin's Chemie*, Bd. i. 213—223.

5. *Latent heat.* a. *Liquids.* When solids are sufficiently heated they fuse, become liquid, and most of them heated still higher are converted into gas or vapor. In both cases, a certain amount of heat is said to be absorbed, or become *latent*, because, although the thermometer shows no increase in heat, yet a considerable quantity may be obtained from them. Each solid, in becoming liquid, seems to absorb a specific amount, which it retains as long as it is kept in the liquid state, and hence it is termed the heat of liquidity or of liquefaction.

When a pound of water at 32° is mixed with a pound of water at 172°, the resulting mixture will show the medium temperature of 102°, but if the former pound were ice at 32°, then the resulting heat of the 2 lbs. of water would be but 32°. Hence, $172 - 32 = 140^\circ$ of heat have disappeared. If 1 lb. water and 1 lb. ice, each at 32°, be exposed to the same heat until the ice is melted, while the latter has been receiving heat, and only shows the temperature of 32°, the water has risen to 172°. The heat of liquefaction has been ascertained in but few bodies. In the following table, the 1st column of numbers shows how

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much each liquid body itself would be heated by the heat it absorbs in fusing, and the 2d how much this heat would heat an equal weight of water.

Water.....	140	140-00
Sulphur.....	144	27-14
Lead.....	370	11-00
Zinc.....	493	48-30
Bismuth.....	550	23-25

From this absorption of heat while melting, the melting of ice offers us a convenient and uniform standard of temperature, which is employed in determining one of the points on the thermometer, the *freezing point*. Connected with this subject is the absorption of heat by solution of salts. See FUSION and FREEZING MIXTURES.

As far as is known, water contains the largest amount of latent heat. It is therefore slowly solidified in freezing, and ice is equally slow in melting. Hence the wisdom apparent in the economy of nature, by the comparative slow changes of temperature on the surface of the earth. When water freezes, it diminishes the intensity of cold by giving off its latent heat, and by slowly melting, it absorbs the heat gradually.

b. *Vapors*. Most liquids and solids, when sufficiently heated, pass into the state of vapor, and as long as they retain this state, resemble the permanent gases. Vapors, and probably gases, hold an amount of latent heat, but that of the latter cannot be determined, unless we can obtain the gas in a liquid or solid state. That of the former may be measured by observing the quantity of heat given out by its condensation, the quantity of water it will heat through one or a given number of degrees, or the number of degrees it will raise a given amount of water. To obtain this amount, observe the weight and temperature of water, conduct the vapor into it, note the then temperature and increased weight of the mixed water and condensed vapor. Then multiply the increased number of degrees of heat by the weight of the water, (the weight of the condensed vapor being unity,) subtract from this the loss of heat sustained by the condensed vapor, between its boiling point and the resulting temperature. Thus, if steam were conducted into 8 oz. water at 60°, until there were 9 oz., and the temperature were then 188°, the ounce of condensed steam has raised the 8 oz., 128° (= 188° - 60°). This heat would therefore have raised 1 oz. $128 \times 8 = 1024^\circ$, but the ounce of condensed steam has lost 24° (212° - 188°). Hence, $1024 - 24 = 1000$ would be the latent heat of steam. Experiments have shown it to be nearly this amount. The following table shows the latent heat of the vapor of several bodies.

Water.....	1000°	1000°
Alcohol.....	374°	609°
Ether.....	163°	314°
Spirits of turpentine.....	138°	299°
Sulphur. carbon.....	144°	—

The 1st column of numbers shows the latent heat of the vapors measured by water, the 2d

HEAT.

their latent heat at their several boiling points. The second column numbers may be found by dividing those of the first by the specific heat of the several bodies.

The latent heat of steam is extensively applied to boiling liquids, warming buildings, drying substances, &c., for which purpose it is conducted through iron pipes and tubes, provision being always made for drawing off the condensing water at the lowest points of the pipe.

6. *Chemical Effects*. a. *Change of color* is produced in many bodies by heat, and the original color restored on cooling. A darker color is always produced, and it is yellow, red, or brown. Peroxide of nitrogen, NO_2 , is colorless at -4°, yellowish at 32°, orange-yellow at 68°. The white titanite, columbite, molybdenite, and antimonious acids become lemon-yellow; yellow sulphur and antimonious acids, brownish yellow; bi- and tri-sulphurets of arsenic, reddish brown; red precipitate, brownish black; the white sulphate, the yellow basic nitrate, and subiodide of mercury, red. In some cases, the change of color may be ascribed to incipient decomposition.

b. *Decomposition*. Where a body which usually has a gaseous form is held in combination with another, for which its affinity is not very strong, the compound may be decomposed by heat alone, as in complex organic and many inorganic bodies. The oxides of the precious metals are wholly reduced; bin-oxides of lead and manganese part with a portion of their oxygen; some of the haloid salts of the precious metals evolve all of the halogen body; most sulphates and nitrates are wholly or partly decomposed, the acid itself suffering decomposition; all carbonates, save those of the fixed alkalies lose their acid. The effect in these cases may be ascribed to the repulsion of the particles of a substance, caused by heat.

Decomposition may be effected by the assistance of heat, where an affinity is exerted to produce this decomposition, but is insufficient to effect it alone. Thus, iron does not decompose water at ordinary temperatures, but steam passed over it at a high heat forms oxide of iron, and evolves hydrogen. In general, heat is used to assist affinity, an effect due to its repulsive effects tending to decompose an existing compound. But it would seem, that different degrees of heat produce different and often contrary effects. Thus, a moderate degree of heat applied to some silicates causes them to suffer an incipient decomposition, for it renders them more easily soluble in muriatic acid; on the other hand, a higher heat applied to the substance thus half disintegrated, will cause its constituents to unite together again as firmly as at first. At one temperature silver oxidizes in the air, at a higher it is again reduced.

c. *Composition*. The union of many bodies is assisted by heat. Few solids unite simply by force of affinity, their cohesive force apparently predominating. But when heat is applied to two bodies having a mutual affinity, sufficient to bring one into fusion, its cohesive force being nearly counterbalanced by the

repulsive effect of heat, its affinity exerts nearly all its power, and causes it to unite with the other body. Hence the facility of making solutions of salts in water, of making amalgams, sulphurets, &c. But some gases will unite together by the application of heat, as chlorine and hydrogen exposed to a brick heated to 300°. In like manner, oxygen combines with iron, nickel, cobalt, &c., at a high heat previous to their entering into fusion. At first sight, the contrary might be anticipated, from the repulsive action of heat on the oxygen; but in the gas the cohesive force is already destroyed, and heat merely expands it, while in the iron, it weakens its cohesive force, and leaves its affinity proportionally stronger.

7. *Evolution of Heat.* In the combustion of substances in the air or oxygen, the amount

of heat developed was supposed by Welter to be the same for hydrogen, carbon, &c., in combining with the same quantity of oxygen. But different experimenters have obtained different results, and the subject requires farther investigation. See COMBUSTION.

The experiments of Hess are full of interest in regard to the amount of heat developed by the union of bodies without the appearance of combustion. 1 eq. anhydrous sulphuric acid (= 40 pts. by weight) mixed with an excess of water, evolves as much heat as would heat 20202 pts. of water through 1° of the Centigrade thermometer, or would heat 1 pt. of water 20202° on that scale. In the following tables the Centigrade thermometer only is used. These pts. of water, or degrees, are termed *heat-units*.

		Units of heat.	With excess of water.
SO ₃ gives with	HO	12432 = 8 · 1554	20202 = 13 · 1554
HO, SO ₃ “	HO	3108 = 2 · 1554	7770 = 5 · 1554
2 HO, SO ₃ “	HO	1554 = 1 · 1554	4662 = 3 · 1554
3 HO, SO ₃ “	3 HO	1554 = 1 · 1554	3108 = 2 · 1554
6 HO, SO ₃ “	mHO	1554 = 1 · 1554	1554 = 1 · 1554
		20202 = 13 · 1554	

mHO signifies so much water, that the farther addition of it evolves no more heat. Calling 1554 a heat-equivalent, anhydrous sulphuric acid evolves 13 such equivs., 8 with

the 1st eq. water, 2 with the 2d, 1 with the 3d, &c. The last column shows, that oil of vitriol, SO₃, HO, evolves 5 such equivs., with an excess of water, &c.

		Units of heat.	With excess of water.
HO, NO ₅ gives with	HO	1554 = 1 · 1554	7770 = 5 · 1554
2 HO, NO ₅ “	HO	1554 = 1 · 1554	6216 = 4 · 1554
3 HO, NO ₅ “	2 HO	1554 = 1 · 1554	4662 = 3 · 1554
5 HO, NO ₅ “	HO	777 = $\frac{1}{2}$ · 1554	3108 = 2 · 1554
6 HO, NO ₅ “	2 HO	777 = $\frac{1}{2}$ · 1554	2331 = $1\frac{1}{2}$ · 1554
8 HO, NO ₅ “	mHO	1554 = 1 · 1554	1554 = 1 · 1554
		7770 = 5 · 1554	

NO₅, HO evolves with an excess of water as much heat as SO₃, HO. The total quantity of heat evolved by either acid is the same, whether the water be added successively in equivs. or all at once; thus SO₃ evolves with HO 8 equivs. of heat, and HO, SO₃ with excess of water 5 such equivs., making altogether 13 equivs., which is the same as that produced by SO₃ with an excess of water.

In like manner, oil of vitriol, HO, SO₃, evolves an equal amount of heat by combining with dilute solutions in excess of potassa, soda or ammonia, about 24000 units of heat. Muriatic acid, spec. grav. 1.125 = 8 HO, HCl, evolves about 14500 with those alkalies; 8 HO, NO₅ gives 16000. Lime, although slacked and diluted with water, gives more units of heat than the alkalies, which Hess attributes to its salts containing crystal-water even in solution.

Evolution of heat also takes place by compression, as by condensing a gas, by hammering or boring iron. When a liquid enters a porous inorganic body without chemical union, the rise of temperature is from 0.36° to 0.9°, when into organic bodies, probably from their greater porosity, it rises from 1.8° to 18°.

HEAVY SPAR. *Min.* Syn. Sulphate of

Barytes, Bolognian Spar, Cawk, Lithespor, Baroselenite. *Ger.* Schwerspath, Stangenspath, Hepatit. *Fr.* Barytine. Cryst. Right Rhombic, presenting a great variety of combinations of vertical and horizontal prisms with the end planes. Cleavage perfect, parallel to main end plane and vertical prism. It also occurs fibrous, columnar, foliated, granular and earthy. H. = 2.5—3.5. G. = 4.3—4.7. Color white, often tinted; vitreous; transparent, opaque; generally translucent.

Chem. Rel. Decrepitates by heating; fuses with difficulty, or rounds on its edges, and partially forms a sulphuret in the reducing flame. It is not decomposed by acids. When pure, it is simply sulphate of baryta with the formula BaO, SO₃.

Local. It is frequently associated with ores, and forms considerable masses in secondary rocks. Its localities are very numerous in Europe and the U. S. The lead mines of the West afford large quantities. Those in Missouri, below St. Louis, supply the market in part. When of a white color, it is ground finely and mixed with white lead, often to the extent of equal weights. When colored slightly by iron, sulphuric acid is used to cleanse it

HEDENBERGITE. See AUGITE.

HEDYPHANE.

HEDYPHANE. *Min.* Amorphous, and in 6-sided prisms. $H. = 3.5 - 4.$ $G. = 5.46 - 5.49.$ Color and streak white; lustre adamantine or subresinous; translucent. It fuses, giving arsenical fumes, and when arsenic predominates over phosphoric acid, it remains as a fused crystalline globule. Hedyphane is one of the mixed arsenio-phosphates of lead. For the formula, see **ARSENIO-PHOSPHATES.** It occurs at Långbanshyttan, Sweden.

HELIOTROPE. See **QUARTZ.**

HELLEBORE, WHITE. The poisonous root of the *Veratrum album.* Its composition is fatty, yellow coloring, and ligneous matters, gallic acid, starch, gum, phosphate of lime, carbonates of lime and potassa, *cevadac(?) acid,* *VERATRIN, barytin,* and *jervin.*

Cevadic Acid. Volatile, and extracted by warm ether, together with the fixed matter from which it is separable by saponification with potassa and the action of baryta. By sublimation, it forms white pearly needles, fusible at $68^{\circ},$ and soluble in water, ether, and alcohol. Is found also in the seed of the *Veratrum sabadilla.*

Barytin. A new alkaloid, precipitable from its acetic or phosphoric solution by sulphuric acid, or the sulphates. *Simon.*

Jervin. Formula $C_{60}H_{45}N_2O_5,$ (*Will.*) A crystalline fusible powder, insoluble in water, but soluble in alcohol, and forming salts with the acids of which the sulphate, nitrate, and hydrochlorate are very sparingly soluble.

HELLENIN. See **ELECAMPANE.**

HELVIN. *Min.* Cryst. Regular, Pl. VIII., fig. 12, both right and left. $H. = 6 - 6.5.$ $G. = 3.1 - 3.3.$ Wax-yellow, siskin-green; vitreous; subtranslucent; fracture uneven, and streak white. Fuses with effervescence in the interior flame to an opaque yellow bead, gives manganese reaction with borax; fuses with soda to a blackish hepar. Decomposed by muriatic acid, with evolution of sulphuretted hydrogen, and leaving gelatinous silica. Berzelius' formula is $3(MnS, MnO) + 3MnO, 2SiO_3 + 2(G_2O_3, SiO_3 + Fe_2O_3, SiO_3);$ but, according to Awdejew's new determination of glucina, the formula is $MnO, MnS + 3(2RO, SiO_3),$ in which $RO = MnO, FeO, GO.$ It is a mineral of most singular composition. It occurs at Schwarzenberg, Saxony, and Modum, Norway.

HEMATITE. See **BROWN HEMATITE,** and **SPECULAR IRON.**

HEMATOSIN. Exists along with *globulin* in the clots or globules of blood. As usually obtained in its coagulated form, it is dark-brown, insoluble in water, alcohol, and ether, but with alkaline or acidified alcohol forms red solutions. Its compounds with the mine-
rable acids are insoluble in water, but soluble in alcohol. Mulder's formula is $C_{44}H_{22}N_3O_6,$ and 1 eq. of iron when ferri-ferous, for its color is not due to this metal, which is present integrally, and not as an oxide. Though having many properties analogous to those of albumen there is no connection with either it or protein. Its per centage of iron is 6.64.

HEMIDESMUS INDICUS. The *Ununtamul* of the Bengalese. The root of this plant is successfully used on the coast of Madras and

HETEROZITE.

in England as a substitute for sarsaparilla. It is long and slender, with few ramifications, covered with rust-colored, fragrant bark. For further description, see *Chem. Gaz.* i. 379.

HEMIPINIC ACID. See **NARCOTIN.**

HEMLOCK. See **CONIUM MACULATUM.** M. Meyer proposes tannic acid as an antidote for the poisonous effects of this vegetable. The dose is given after the evacuation of the stomach by an emetic, and is to be assisted by cold applications to the head, and friction of the cold extremities of the patient. *Chem. Gaz.* vol. ii., p. 109.

HEMP. The plant *Cannabis sativa.* By distillation, yields a *volatile oil.* The resin of hemp (*Cannabin*) is bitter, but fragrant, and soluble in alcohol and ether. The *Churrus* of the Asiatics is the concreted resinous exudation from the leaves, stems, and flowers of the *Cannabis Indica.* The *momeca* is a better quality of churrus. The *gunjah* is the dried flowered plant itself, and the *bang, subjee,* or *sidhee,* the larger dried leaves and capsules, without the stalks.

The *Hudschy* of the Turks is prepared from the *C. sativa.* (*Chem. Gaz.* ii. 218.) The difference between the two species is not essential. (*Pereira.*) The seeds of the latter, as analyzed by Bucholz, contain

Fat oil	19.1
Albumen	24.7
Brown gum	9.0
Bitter extract, with sugar	1.6
Hard resin	1.6
Fibre, hulls, &c.	43.3

99.3

Oil. Is greenish yellow, when first expressed, but loses its green tint after a time. Congeals at $16.6,$ is soluble in hot alcohol, but when cold this solvent takes up but one-thirtieth of its weight. It is used for making soft soaps, in painting, and illumination, but for this latter purpose, its siccative tendency must be nullified by the addition of 12 pr. ct. of butter. The *alcoholic* or *resinous extract* of (*Cannabis*) *Indian* hemp is the inspissated tincture of the adhesive tops of the *gunjah.* *Majoon* is a confection of hemp used in India and Turkey for the purpose of intoxication.

* **HEPATITE.** See **HEAVY SPAR.**

HERDERITE. *Min.* Allogonite. Right Rhombic. $H. = 5.$ $G. = 2.985.$ Yellowish and greenish white; vitreous; translucent; very brittle, with small conchoidal fracture. Not analyzed.

HERRERITE. *Min.* Cryst. probably Hexagonal. $H. = 4 - 5.$ $G. = 4.3.$ Emerald green; vitreous, shining; translucent; streak yellowish gray. Contains tellurium, nickel, and carbonic acid, but requires farther investigation. It occurs at Albarradon, Mexico.

HERSCHELITE. *Min.* Cryst. Hexagonal, cleavage parallel to terminal plane. $H. = 4.5.$ $G. = 2.11.$ White; translucent, opaque.

HETEROZITE. *Min.* Heteposite. Oblique Rhombic. $H. = 6.$ $G. = 3.5.$ Greenish or bluish; resinous. By exposure becomes violet and submetallic. Fuses to a dark brown enamel. Soluble in acids. Formula

HEULANDITE.

$2(5\text{FeO}, 2\text{PO}_5) + 5\text{MnO}, 2\text{PO}_5 + 5\text{HO}$.
Local. Thoreaux, Haute Vienne, France.

HEULANDITE. *Min.* Syn. Stilbite (in part). Foliated Zeolite, Euzelolite, Lincolnite, Beaumontite. *Ger.* Blattriger Stilbit, Blätterzeolit. *Cryst.* Oblique Rhombic, with a very perfect pearly cleavage. $H. = 3.5 - 4$. $G. = 2.2$. White, red, gray, brown; vitreous, and pearly on cleavage; transparent, subtranslucent; brittle, with uneven, subconchoidal fracture. Acts like zeolites, yielding water, intumescing and fusing; dissolves in muriatic acid without gelatinizing. Formula $3(\text{CaO}, \text{SiO}_3) + 4(\text{Al}_2\text{O}_3, 3\text{SiO}_3) + 18 \text{ or } 21\text{HO}$. *Local.* In Trappean rocks, associated with other zeolites.

HIPPURIC ACID. *Chem.* It occurs in the urine of graminivorous animals, and may be obtained by evaporating the fresh urine of the horse or cow, at a gentle heat below boiling, and when concentrated, adding muriatic acid, until there is an acid reaction, when hippuric acid crystallizes out by standing. It is also prepared by adding a little milk of lime to the urine, removing the excess of lime, boiling down rapidly to $\frac{1}{3}$ its bulk, and adding muriatic acid; the crystals are purified by solution in lime, and reprecipitation by acid. (*Gregory.*) It may be similarly prepared from the urine of man, when a dose of benzoic acid has been previously administered. It is decolorized by chlorine and recrystallized. It appears as long needles, of a feeble, bitterish taste, fusing to an oily liquid, and congealing to a crystalline mass on cooling; soluble in water, alcohol, and slightly in ether.

Dessaignes proved that by continued boiling with muriatic acid, it is resolved into benzoic acid and chloro-hydrate of glycocoll, which shows that hippuric acid is the benzoic, paired with sugar of gelatin (glycocoll). Nitric, sulphuric, and oxalic acids, and potassa effect a similar metamorphosis of hippuric acid.

Form. $\text{C}_{18}\text{H}_9\text{NO}_6$. If from this benzoic acid $\text{C}_{14}\text{H}_5\text{O}_3$ be subtracted, sugar of gelatin $\text{C}_4\text{H}_4\text{NO}_3$ remains in its anhydrous state. The rational formula of the acid is therefore $\text{C}_{14}\text{H}_5\text{O}_3 + \text{C}_4\text{H}_4\text{NO}_3$. This paired acid forms a series of salts with bases, those of the metals proper being difficultly soluble in cold, more soluble in hot water, and crystallizable from the solution.

HIRCIN. Exists in the fat of the goat, with olein as the liquid portion, and probably also in the leaves of *Hypericum hircinum*, which have a similar strong odor. It is more soluble than olein in alcohol. By saponification hircic acid is eliminated, and can be separated as are the volatile acids of butter.

Hircic Acid. Is a volatile liquid, lighter than water, and slightly soluble therein. It remains fluid at 0° , and form salts with the bases, of which the hircates of potassa and baryta are soluble in water. Its formula has not yet been determined.

HISINGERITE. *Min.* Thraulite. Crystalline, with one cleavage. Soft. $G. = 3.045$. Black, opaque, sectile, cross fracture earthy; streak greenish gray or brownish yellow. Gives water in a tube; becomes magnetic on

HOPS.

charcoal, giving the reactions of silica and iron. Decomposed by acids. *Form.* $\text{FeO}, \text{SiO}_3 + \text{Fe}_2\text{O}_3, \text{SiO}_3 + 6\text{HO}$. *Local.* Riddarhyttan, Bodenmais.

HOGANITE. See MESOTYPE.

HOLLOW SPAR. See CHIASTOLITE.

HOLMSITE. See CLINTONITE.

HOMBERG'S PHOSPHORUS. A PYROPHORUS made by mixing over the fire a mixture of equal weights of alum and brown sugar.

HONEY. Syn. *Lat.* Mel. *Fr.* Miel. *Ger.* Honig. The saccharine secretion collected by the hive bee (*Apis mellifica*) from the nectariferous glands of flowers. The delightful flavor of Narbonne honey is due to the labiate flowers on which the animal feeds, for both the odor and taste of honey varies according to the age of the bees, and the nature of their food. It is deposited in combs composed of wax, and when separated therefrom by pressure, consists of odorous, coloring, gummy, and waxy matters, a crystallizable sugar analogous to grape sugar, and another uncrystallizable, and similar to the brown syrup of sugar cane. In addition to these, Guibourt found mannite.

To prevent its liability to fermentation, and render it fit for use, the crude honey requires to be purified of certain impurities with which it is always mixed. It is then termed

Mel despumatum. Vogel's method of purification is to beat 5 lb. with the white of one egg until it froths, and then add water enough to give it a syrupy consistence. It is then mixed and boiled until the albumen can be removed with the froth. It is then poured in an upright vessel, which carries a cock two or three inches from its bottom. Being covered and set aside for several weeks, the impurities subside, and the clear honey can then be racked off through the cock.

HONEYSTONE. *Min.* Mellite, Mellilite, Mellate of Alumina; Honigstein. *Cryst.* Quadratic. $H. = 2 - 2.5$. $G. = 1.55 - 1.597$. Honey-yellow, reddish, brownish; resinous; transparent, translucent; sectile, with conchoidal fracture, and white streak. Yields water in a tube; chars by ignition, burns white on coal, and then acts like alumina. *Form.* $\text{Al}_2\text{O}_3, 3\text{M} + 15\text{HO}$. Decomposed by acids, caustic alkali, and boiling water. *Local.* Asstern in Thuringen, in brown coal. See MELLITIC ACID.

HOPEITE. *Min.* Zinkphyllit. Right Rhombic, cleavage perfectly parallel with an end-plane. $H. = 2.5 - 3$. $G. = 2.76$. Grayish white and brownish; vitreous, subpearly on cleavage; transparent, translucent, with double refraction; sectile, with white streak. Yields water in a tube; and fuses to a clear colorless bead, tinging the flame green; with soda gives fumes of zinc. Supposed to contain phosphoric acid, zinc, cadmium, and water.

Local. Zinc mines of Aix la Chapelle.

HOPS. The aggregate fruits or strabiles of the *Humulus Lupulus*. They consist of scales, nuts, and lupulinic glands.

Chevalier and Payen's analysis of the scales gave astringent and inert coloring mat-

HORDEIN.

ters, chlorophylle, gum, lignin, ammonia, potash, and lime salts as their composition.

The lupulinic grains consist of

Volatile oil	2.00
Lupulin	10.30
Resin	55.00
Lignin	32.00
Fatty, astringent, and gummy matters, osmazome, malic acid, earthy, and alkaline salts	traces

Volatile Oil. Yellowish, acid, soluble in alcohol, ether, and water. Spec. grav. 0.910. Obtained by distilling the lupulinic grains with water. It is fluid, but by keeping resinifies, and, from its property of blackening silver vessels, is supposed to contain sulphur. One cwt. yields 3 ounces.

Resin. Probably the oxidized oil. Is golden-yellow, but darkens on exposure. Soluble in alcohol and ether.

Lupulin. Syn. Lupulite. The bitter principle of hops. Yellowish white, bitter, uncrystallizable, neutral, soluble in alcohol, less so in ether, and in 20 pts. of water. Decomposable by heat, without the production of ammonia. It is extracted by the addition of water to an inspissated alcoholic tincture of the pollen of the flowers, and neutralizing the liquid separated from the precipitated resin by lime, which removes the tannin and malic acid. The evaporated filtered solution, by treatment with ether yields lupulin. By further solution in alcohol, it may be obtained in crystals.

According to Redtenbacher, lupulin, the astringent substance, and the aromatic oil, are the only constituents of the hop which enter into the composition of BEER. In brewing, therefore, it would be a great economy to use the aqueous extract, and add the oil when the beer is filled into the fermenting vats. See *Polytech. Central Blatt.* 1843, No. 13.

HORDEIN. See BARLEY.

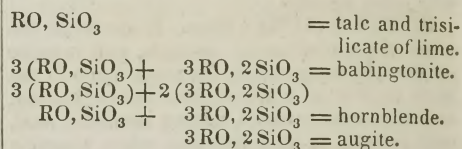
HORNBLLENDE. *Min.* Syn. Tremolite, Calamite, Actinolite, Pargasite, Smaragdite, Asbestos (in part), Amianthus, Amianthoid, Lotalite, Amphibole. *Ger.* Actinot, Strahlstein, Gramatit, Byssolith. *Descrip.* Cryst. Oblique Rhombic, presenting a great variety of combinations similar to those of augite and felspar, Pl. IX., figs. 34, 35, 36, with a perfect lateral cleavage. It also occurs fibrous (asbestos, tremolite), columnar, granular.

H. = 5—6. G. = 2.9—3.4, according to its content of iron. Color black, and greenish black, (hornblende, arfwedsonite,) green, (actinolite, smaragdite, pargasite, &c.,) white, (tremolite, grammatite.) The prevailing color is green, with a white, grayish, or brown streak. Lustre generally vitreous. Rarely transparent, usually subtranslucent, opaque. Brittle, with uneven, subconchoidal fracture.

Chem. Rel. Their behavior varies. They are all fusible, generally intumescing, to a gray, greenish, or black glass. Partially attacked by acids. It is closely allied in the number and nature of ingredients to augite. The general formula is $RO, SiO_3 + 3 RO, 2 SiO_3$; in which RO is magnesia, lime, protoxides of iron and manganese. In some

HORN Y MATTER.

hornblendes the quantity of alumina is very large, amounting to 15 pr. ct., and it seems to increase in proportion as the silice diminishes, so that it is impracticable to give a general formula for hornblende, unless we assume with V. Bonsdorf, that 3 eq. alumina may replace 2 eq. silica. A. Those free from alumina. 1. $CaO, SiO_3 + 3 MgO, 2 SiO_3$, as tremolite, grammatite, actinolite. 2. $FeO, SiO_3 + 3 MgO, 2 SiO_3$, antophyllite. 3. $NaO, SiO_3 + 3 FeO, 2 SiO_3$, arfwedsonite, aigirin. B. aluminous. Rammelsberg gives a series of bi- and tri-silicates, which require close research in order to throw light upon the hornblende and augite series.



Local. The localities are very numerous. It occurs in large veins, or spangling primary rocks like mica (hornblende slates, gneiss, &c.), and is a necessary constituent of syenite and greenstone. Actinolite occurs frequently in talcose rocks, and tremolite in granular limestone. Asbestos is found in serpentine and other primary rocks. Some of the finer translucent green varieties have been employed as gems. Those rich in iron have been added as flux to iron ores and to glass mixture to make bottle glass.

HORN MERCURY. *Min.* Native Calomel. Quecksilberhornerz. Cryst. Quadratic; also granular. H. = 1—2. G. = 6.482. Yellowish and grayish white; adamantine; translucent, subtranslucent; sectile, with conchoidal fracture and white streak. Volatile on charcoal; sublimes in a tube without fusion as a white mass, and heated with soda as metallic mercury. Form. Hg_2Cl . It is of rare occurrence in quicksilver mines.

HORN SILVER. *Min.* Syn. Muriate or Chloride of Silver; Hornerz, Hornsilber. Cryst. Regular. Pl. VIII., figs. 1, 2, 3, 8, 9. Usually massive, and often imitative. H. = 1—1.5. G. = 5.552. Pearl-gray, blue-gray, and green, becoming brown by exposure to light; resinous, subadamantine; translucent, nearly opaque; sectile, with conchoidal fracture, and shining streak. Fusible, with intumescence, to a gray, brown, or black bead, which may be gradually reduced to silver. Form. $AgCl$. It is common in silver mines, and is the most abundant silver ore in Chili.

HORNSTONE. See QUARTZ.

HORN Y MATTER. Is that product of the animal organism not subject to re-absorption.

Membranous horny matter constitutes the epidermis, and also the epithelium in its different modes of formation. When dried at 212° and burned, it leaves 1 pr. ct. of earthy ashes.

Compact horny matter embraces hair, hoofs, nails, wool, and silk. Both the membranous and compact contain sulphur, together with carbon, hydrogen, nitrogen, and oxygen. Each of the above substances, on being burned, give more or less of earthy ashes. To exhibit the

HORSERADISH.

relation of this class of substances to **PROTEIN**, Scheerer gives $C_{48}H_{39}N_7O_{17} = Pr + NH_3 + 3O$, as the empirical formula of compact horny matter. The solution of hair or horny substances in caustic potassa is attended with an evolution of ammonia and the formation of some acetic acid. A further quantity of acetic acid neutralizes the solution, disengages sulphuretted hydrogen, and precipitates protein. (*Von Laer*.) From the supernatant liquid, binoxide of protein is separable by renewed application of acetic acid.

Feathers are also embraced under this head, but, according to Scherer, they contain one eq. less of oxygen.

HORSERADISH. See **COCHLEARIA**.

HUDSONITE. See **AUGITE**.

HUMBOLDTILITE. *Min.* Mellilite, Sarcilite. Cryst. Quadratic, the prism. $H. = 5$. $G. = 2.9 - 3.1$. Brown, yellow; vitreous; translucent; fracture conchoidal, uneven. Fuses with difficulty without becoming opaque. Decomposed by acids, silica gelatinizing. Form. $2(3RO, SiO_3) + R_2O_3, SiO_3$; in which $RO = CaO$, with MgO, NaO, KO . R_2O_3 is Al_2O_3, Fe_2O_3 . *Local.* Vesuvius.

HUMBOLDTIN. *Min.* Humboldtite, Oxalite, Eisenresin. Earthy; soft. $G. = 2.13 - 2.489$; yellow, dull. Blackens in lamp flame, and becomes magnetic; on coal it becomes black, then red. Decomposed by acids and alkali. Form. $2(FeO, C_2O_3) + 3HO$. *Local.* Koloseruk, Bohemia.

HUMITE. *Min.* Right Rhombic, in minute and highly modified crystals. $H. = 6.5 - 7$. $G. = 3.1 - 3.2$. Yellow, vitreous, transparent, translucent; streak white; fracture subconchoidal. It is not unlikely that this species and chondrodite are identical. *Local.* Monte Somma.

HUMUS,
HUMIC ACID. } See **MOULD**.

HURAILITE. *Min.* Cryst. Oblique Rhombic. $H. = 3 +$. $G. = 2.27$. Reddish yellow, vitreous, transparent. Easily fusible to a black bead, with metallic lustre; yields water in a tube. Form. $3(5MnO, 2PO_3) + 5FeO, PO_3 + 30HO$. *Local.* Limoges, France.

HURONITE. *Min.* Imperfectly crystallized. $H. = 3.25$. $G. = 2.86$. Light yellowish green; pearly to greasy; translucent; gray streak. Heated, it becomes gray-white, and is infusible. Not decomposed by acids. Form. $3RO, 2SiO_3 + 4(Al_2O_3, SiO_3) + 3HO$. *Local.* Lake Huron.

HYACINTH. See **ZIRCON**.

HYALITE. See **OPAL**. The name is also given to black **GLASS**.

HYALOMICT. *Geol.* A friable granular quartzose rock, containing very little mica.

HYALOSIDERITE. See **CHRYSOLITE**.

HYDRACIDS. *Chem.* Those consisting in the dry state of hydrogen and another element, or simple radical, such chlorohydric (muriatic) acid, HCl ; fluohydric, HF ; cyanohydric (prussic), $HCy = H, NC_2$. According to one theory, sulphuric and other acids may be regarded as hydracids, thus oil of vitriol, $HO, SO_3 = H, SO_4$, in which SO_4 is the radical.

HYDRARGILLITE. *Min.* Hexagonal, with perfect cleavage. $H. = 2.5 - 3$. Light red-

HYDROGEN.

dish white, translucent; cleavage pearly. It yields water in a tube; gives a brilliant light, is infusible, and gives a brilliant blue with cobalt solution. It appears to be a simple hydrate of alumina. From Slatoust in Ural. See **GIBBSITE**.

HYDRARGO-CHLORIDES. A family of haloid compounds, in which the acid is bichloride of mercury; for example, the hydrargo-chloride of potassium.

HYDRARSINE. See **KAKODYLE**.

HYDRATE. *Chem.* A compound of water with a metallic oxide or an acid, as hydrate of potassa (caustic potash), KO, HO . See **HYDROGEN**.

HYDRIODIC ACID. See **IODINE**.

HYDRO- A prefix employed in mineralogy to signify water as a constituent of the mineral, as **HYDROBORACITE**; and in chemistry to denote a compound of hydrogen, as **HYDRO-CARBON**.

HYDROBENZAMIDE. See **BENZYL**, p. 314.

HYDROBORACITE. *Min.* Resembles fibrous and foliated gypsum. Gives water in a tube, and fuses easily to a clear glass. It is slightly soluble in water, with alkaline reaction; very soluble in hot nitric and muriatic acids, from which, on cooling, boracic acid separates. Form. $3CaO, 4BO_3 + 3MgO, 4BO_3 + 18HO$. *Local.* Caucasus mountains. See **BOROCALCITE**.

HYDROBOROCALCITE. See **BOROCALCITE**.

HYDROBROMIC ACID. See **BROMINE**.

HYDROCARBON. See **HYDROGEN**.

HYDROCARBURETS. Compounds of carbon and hydrogen, of which the illuminating gas is the most familiar.

HYDROCHLORATES. Syn. Muriates. Compounds of hydrochloric acid with bases.

HYDROCHLORIC ACID. See **CHLORINE**.

HYDROCYANIC ACID. } See **CYANOGEN**.

HYDROCYANATES. }

HYDROFERRID-CYANIC ACID. }

HYDRO-FERRIDCYANATES. } See **CYANOGEN**.

HYDROFLUORIC ACID. See **FLUORINE**.

HYDROGEN. *Chem.* Syn. Inflammable gas. *Ger.* Wasserstoff. Discovered after the middle of the last century, and termed inflammable air. Cavendish and Watt proved that in its combustion it united with oxygen and produced water, the exact composition of which by volume was proved by Humboldt and Gay-Lussac.

Prep. 1. Dilute 3 pts. oil of vitriol with 24 pts. water, and dissolve in it 2 pts. zinc, or $2\frac{1}{2}$ pts. iron, in Apparatus, fig. 23, p. 174, **ANALYSIS**. $HO, SO_3 + M = MO, SO_3 + HO$, in which M represents the metal. 2. Dissolve either of these metals in chlorohydric acid, diluted with 2 pts. water. $HCl + M = MCl + H$. 3. Pass steam through a white hot tube, containing iron wire, turnings, &c. $3Fe + 4HO = Fe_3O_4 + H_2$. 4. Thrust potassium under an inverted glass filled with water. The hydrogen rises in the glass, and potassa is dissolved. $HO + K = KO + H$.

The first is the usual way of preparing hydrogen. When made from commercial zinc and common acid, the gas may contain sul-

phuretted, phosphuretted, and arseniuretted hydrogen, sulphurous acid, and nitric and nitrous oxides. The last 3 arise from the acid, the first 2 from the metal, and both acid and metal may contain arsenic. Iron yields besides these impurities a carburetted hydrogen from its carbon, and ferruretted hydrogen.

Prop. Colorless gas, inodorous and tasteless, when pure, ordinarily with an odor from impurities; spec. grav. 69.3, $14\frac{1}{2}$ times lighter than the air; refractive power = 0.47 (air = 1). Very combustible, but does not support combustion; uniting with oxygen to form water. It destroys life rather by excluding oxygen than by its own injurious effects. It unites readily with oxygen by fire, electricity, a platinum surface, and sudden compression evolving light and heat; with chlorine by the same, and in sun-light. It forms $\frac{1}{8}$ part of water, and is a constituent of all organic bodies; it is therefore one of the abundant elements. Sym. H = 1, the unit of comparison on the hydrogen scale. H = 12.5 when O = 100.

Uses. From its levity it is employed to inflate balloons. It is a powerful reducing agent in the hands of the chemist. Burned together with oxygen, it constitutes the Hydrogen Blowpipe. A jet of hydrogen thrown on platinum sponge in the air is readily ignited; Döbereiner's Hydrogen lamp.

Compounds. 1. *With oxygen or water.* Formed by burning hydrogen in the air or in oxygen. Obtained pure by distilling rain, river, or spring water in a copper still with tin head and worm. A glass retort yields alkaline salts. Air may be removed by simple boiling.

Prop. Water is a colorless, transparent, tasteless, inodorous liquid, when pure, spec. grav. = 1.00, being the unit of comparison for all liquids and solids. A cubic centimeter weighs 1 gramme at 39.2° F.; 1 cub. inch at 60° and 30 Bar. weighs 252.506 grains, (*Schuckburgh*); it is 815 times heavier than atmospheric air. It is scarcely compressible by mechanical force; 0.000045 for 1 atmosphere, and in direct proportion to the force up to 70 atmospheres. (*Oerstedt*.) Its greatest density is at 39° to 39.2° Fahr. = 4° Cent. When cooled below 39° it expands to 32° and below; heated above 39° it likewise expands. Cooled to 32° and agitated, it congeals to ice, which crystallizes in the hexagonal system, and has a spec. grav. = 0.927 — 0.95. When heated to 212° it rises in vapor by boiling. See **EBULLITION**, **EVAPORATION**, **VAPOR**.

Water absorbs gases in very different proportions. See **ABSORPTION**. It is the most universal solvent of solids and liquids. See **SOLUTION**.

Combinations. *Basic hydrates.* Bases take up usually as many equivs. water as they do of acid to form salts, and in combining some of them evolve light and heat, as baryta and lime. Thus caustic potassa, baryta, and slacked lime are single hydrates, the last of which loses its water at a red heat, the other two do not, and potassa may be volatilized, still retaining its water. Most other basic hydrates are easily decomposed.

Acid Hydrates. Acids combine usually with

as many equivs. of water as they do of base to form salts, evolving heat by combining. Thus oil of vitriol = HO, SO₃; the phosphoric acids are HO, PO₃; 2 HO, PO₃; 3 HO, PO₃, &c. The combination is distilled over as a whole in most cases.

Both the above acids and bases combine with more equivs. water to form crystallized bodies; thus cryst. sulphuric acid = HO, SO₃ + HO; cryst. potassa = HO, KO + 4 HO; cryst. baryta = HO, BaO + 8 HO.

Saline Hydrates. Most salts contain combined water, varying in different salts from 1 to 24 equivs.; but some, as common salt, sulphate of potassa, &c., crystallize without water. This water is generally driven off at a low heat, although different equivs. of the water in any one salt seem to combine with different force. Thus, while 4 eq. HO may be expelled from blue vitriol at 212°, it requires 400° to 450° to expel the remaining equivalent. The 4 former equivs. are properly the crystalline water, and the latter water of constitution. When a salt has been deprived of its water, it will usually regain it by exposure to air. Thus dry carbonate of soda assumes in a short time 10 equivs. water, but dry Glauber's salt reassumes none. Carbonate of soda assumes 5 different proportions of water, crystallizing in as many different forms, viz. 1, 5, 6, 8 & 10 equivs. HO. See further, under **WATER**.

b. *Binoxide of hydrogen.* Oxygenated water. *Prep.* from peroxide of barium, calcium, &c. Ignite pure nitrate of baryta in porcelain, break it into nut-sized pieces and put them in a coated glass tube; heat to feeble ignition and pass pure oxygen through it. Decompose this peroxide by fluohydric, or silicofluohydric acid, keeping the whole cool; filter and evaporate in vacuo with oil of vitriol. It is a colorless, transparent, inodorous liquid, taste astringent and bitter; spec. grav. 1.452; does not congeal at — 22°; bleaches litmus; whitens the skin and produces pain; miscible in all proportions with water and with acids, which prevent its easy decomposition. It decomposes slowly by standing, readily by heat; readily and violently by silver, gold, the platinum metals, and charcoal, less violently by other metals; by many metallic oxides; by the oxides of the precious metals which lose their oxygen at the same time; by potassium, arsenic, &c., which take up a part of the liberated oxygen to form base or acid; by sulphurous acid, baryta, &c., which take up all the liberated oxygen.

c. *Ozone* probably belongs to this series. By some it is regarded as an allotropic condition of oxygen, but Bunsen has shown it to be a hyperoxide of hydrogen.

2. *Carbon.* Carbon combines with hydrogen in manifold proportions, and moreover exhibits a large number of isomeric bodies. The following table shows the various proportions between them, the numbers representing the number of equivs. They are usually classed with organic bodies, and their description is referred to other places in this work.

HYDROGEN.

HYDROMETER.

$C_1 H_1$	$C_5 H_4$
2 2 Methylen.	5 4 Hartite.
4 4 Olefiant gas.	20 16 Camphen, &c.
8 8 Butyren.	30 24 Copaiven, &c.
10 10 Amylen, &c.	40 32 Colophen, &c.
12 12 Oleen.	
16 16 Naphthen, &c.	$C_5 H_2$
20 20 Paramylen.	20 8 Naphthalin, &c.
32 32 Ceten, &c.	30 12 Anthracen, &c.
38 38 Heven.	
40 40 Ozokerite.	$C_9 H_8$
	18 16 Campholen.
$C_2 H_1$	36 32 Tekoretin.
12 6 Benzin, &c.	
16 8 Styrole, &c.	$C_m H_n$
20 10 Scheererite.	4 3 Fichtelite.
32 16 Retinole.	14 12 Vol. Naphtha.
	20 18 Menthen.
$C_3 H_2$	24 22 Naphthole.
12 8 Mesitylen.	14 8 Dracyl.
18 12 Cumen, &c.	20 14 Cymen.
	28 12 Stilben.
$C_3 H_1$	36 22 Phylloretin.
24 8 Chrysen.	2 4 Marsh gas.
30 10 Idrialin.	48 50 Paraffin.

Of the above we shall now describe only olefiant and marsh gases.

Olefiant gas. Syn. Light carburetted hydrogen; Etherin, Ethen; Elayl, Berzel. Ger. Oelbildendes Gas.

Prep. 1. Heat a mixture of 1 pt. common alcohol and 4 pts. oil of vitriol in a retort or flask, provided with a tube for passing the gas into glasses over water. To avoid frothing, it is better to heat the 4 pts. of acid with $\frac{1}{4}$ pt. of alcohol until the mixture begins to be black, when the rest is gradually added through an S-tube. *Magnus.*

2. Mix in a retort 10 pts. oil of vitriol with 3 pts. water, until the mixture attains a boiling point of 320° to 329° ; keeping it at this point, pass in a very fine stream of 80 pr. ct. alcohol, or the vapor of the same. As long as this heat is maintained, the acid will catalyze the alcohol into the gas and water, with the exception of a small amount of ether and alcohol, carried over mechanically; the acid remains clear. (See the prep. of ether under ETHER.) The same gas is also obtained in the dry distillation of fats, resins, essential oils, caoutchouc, bitumen, coals, &c. As usually prepared, it contains the vapors of alcohol and ether, carbonic acid and oxide, and sulphurous acid. These may be more or less removed by washing with oil of vitriol and milk of lime. To avoid carbonic acid and oxide, the first $\frac{1}{3}$ of the gas only is caught.

Prop. A transparent, colorless gas, of a disagreeable, suffocating odor; spec. grav. 0.978; condensing by pressure at -160° , into a clear liquid; 1 vol. water absorbs $\frac{1}{4}$ vol. gas. In the air it burns with a brilliant white flame; 1 vol. gas and 3 vols. oxygen, by flame or the electric spark, explode with the greatest violence. It is decomposed by successive electric sparks into carbon and hydrogen; partially decomposed, when passed through an ignited porcelain tube, into marsh gas and

carbon. For its composition and combinations, see ELAYL.

Marsh gas. Syn. Heavy carburetted hydrogen, Pitgas, Fire-damp. *Prep.* Heat in a retort a mixture of 2 pts. cryst. acetate of soda, 2 pts. caustic potassa, and 3 pts. lime. It may also be obtained less pure by passing olefiant or common light gas through an ignited tube, and washing with chlorine and lime. The gas rising when the bottom of a marsh is stirred up, contains 10 to 20 pr. ct. nitrogen mixed with this gas (from decomposing organic matter). *Prop.* Colorless, inodorous, tasteless gas, spec. grav. 0.6; 1 vol. water absorbs $\frac{1}{27}$ vol. gas; very combustible, burning with a moderately luminous and yellowish flame; explodes with 2 vols. oxygen, forming carbonic acid and water; decomposed by electric sparks, or by repeatedly passing through an ignited tube into carbon and twice its vol. hydrogen. Form. CH_4 ($75 C + 25 H = 100.$)

Other compounds of hydrogen see under AMMONIA, CHLORINE, &c., PHOSPHORUS, SULPHUR, &c.

HYDROLEIC ACID. See OLEIN.

HYDROLITE. See CHABAZITE.

HYDROMAGNESITE. *Min.* White crusts and powder. $H = 2$. Behaves like magnesia; effervesces with acid. Form. $3(MgO, CO_2 + HO) + MgO, HO$. Hoboken, N. J., and Negropont, E. India.

HYDROMARGARITIC ACID. } See MARGARIN.
HYDROMARGARIC ACID. }

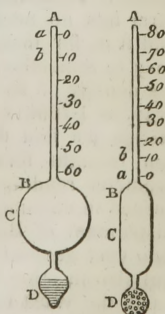
HYDROMEL. The fermented mixture of honey and water, known as a beverage under the name of *Mend*.

HYDROMETER. Ger. Aräometer; Fr. Aréomètre. This is a simple instrument, which is often used for determining the specific gravities, or densities of liquids, and sometimes of solids. It is based upon the hydrostatic law, that a floating body displaces its own weight of the liquid in which it swims. Hence the more dense the liquid, the smaller will be the quantity displaced, or the depth to which a hydrometer will sink in it.

It is evident, that by varying the weight required to sink a body of given bulk, we may determine the specific gravities of liquids, as well as by measuring the relative volume displaced by one of invariable weight. Hydrometers are, therefore, constructed upon each of these principles, and they may be classified as those of *constant weight* and those of *constant volume*.

Hydrometers of *constant weight* have been varied capriciously and to an almost indefinite extent. They are all made either of metal or glass, and nearly of the shape of the marginal figure, (Fig. 87,) in which A is the graduated stem, BC the bulb, and D a heavy counterpoise which is required to render the equilibrium stable, and keep the instrument always upright in position, when in use.

Fig. 87.



We may of course divide a given magnitude into any arbitrary number of fractional parts; and if the scales of hydrometers be graduated thus capriciously, every country and every man may produce a different instrument. It is in this manner that hydrometers have been multiplied to an extent which is beyond all reason. We shall not, therefore, give an account of those arbitrary hydrometers which have by accident become well known in particular countries, as for instance in England, but refer the reader to books published in such places, and describe only those instruments which are founded upon natural bases, or which have become generally known and used throughout the world.

The stem may be divided so as to indicate specific gravities directly; for this purpose, if we denote by w the weight of the hydrometer, by v the volume of the liquid displaced, and by d its density or specific gravity, we shall have

$$w = dv,$$

as the equation, which will enable us to calculate the volume displaced or immersed for any corresponding density, and to graduate the stem accordingly. This equation is that of the hyperbola; if, therefore, the specific gravities be supposed to vary by equal differences, the corresponding volumes will vary unequally, or the stem must not be divided into equal parts, but into intervals proportionate to the differences of consecutive ordinates of the hyperbola. Such hydrometers are consequently of rather difficult construction, and require skill and intelligence on the part of the manufacturer.

Pure, or freshly-distilled water, at its maximum density, which occurs at the temperature of 39.6° Fahr. nearly, is the most natural and most generally accepted unit of specific gravities. If, therefore, the volume immersed in water of maximum density be divided and subdivided decimally, such a system of graduation for hydrometers may be considered the most natural and simple. Instruments of this kind have been made in France, but they have been very little used; M. Francœur has the honor of being their inventor. One of their greatest advantages is, that their indications may be very readily converted into the corresponding specific gravities by simple and easy arithmetical calculations.

That a hydrometer may be convenient and useful in the arts, it need not, and perhaps it should not read specific gravities: for these are usually expressed in decimal fractions; therefore are recollected with difficulty, and liable to accidental mistakes. The manufacturer has no need of them in his processes, and it is, for instance, far simpler and more easy to remember that an acid or syrup has the density of 20° Beaumé, than that its spec. grav. is 1.166612, that of water being unity. Hence we find that in France, though Brisson brought forward simultaneously a hydrometer reading specific gravities, and succeeded in causing a violent opposition to the instrument of Beaumé; the latter has come into very general use not merely in France, but also in other countries of Europe, as well as in the West Indies and our own country.

Certainly, therefore, the cause of this must lie in the advantages which in the instrument of Brisson were found wanting. The difficulty of construction, and consequent high price, were perhaps the chief reasons why an instrument based on rigid scientific principles was superseded by one depending upon arbitrary and uncertain rules, but which was simple and easy in its construction and use, and being of comparatively low cost, was therefore economical. Hydrometers are furnished of equal accuracy of workmanship and fitness for the same purpose, which vary in cost so much that one is sold for fifty cents and another for twenty-five dollars; they are often injured, and must then be replaced. Certainly, therefore, price is a matter of great moment, and simplicity in construction and employment is of essential importance.

Beaumé's hydrometers. For fluids lighter than water Beaumé invented his *pèse-esprit* (hydrometer for spirits); and for fluids heavier than water, a single instrument called, with reference to its particular application, by the different names of *pèse-acide*, *pèse-sel*, or *pèse-sirop* (acid, salt, or syrup measure). These instruments are entirely distinct, and form no part of a common system, for they are constructed on different bases. The degrees of one are not equal to those of the other; and the zero-point, which is determined for the *pèse-esprit* by a solution containing 10 pr. ct. of common salt, corresponds in the *pèse-acide* to the density of pure water. Hence we shall treat of these instruments separately.

The *pèse-esprit* is constructed by immersion in a solution of common salt, containing, as already stated, 10 pr. ct., to obtain the zero point; then, by plunging it into water to determine another point, which Beaumé calls 10° , the interval is graduated equally, and the scale extended by laying off repeatedly, with a pair of dividers, the same interval upon the stem.

The zero point of the *pèse-acide* is given by the surface of the distilled water in which it floats. Immersion in a solution containing 15 pr. ct. of common salt fixes the point which is to be marked 15° upon the scale. And degrees beyond 15° are determined by the same process of extension employed for the *pèse-esprit*.

It might at first be supposed that the degrees of these instruments would constitute parts of a common scale; but the densities of two solutions of common salt containing one 10 and the other 15 pr. ct., will not be such as to correspond to equal degrees, 10° and 15° , reckoned from water as a common origin; and, therefore, Beaumé's hydrometers belong to different scales.

It is a great and fundamental defect of these instruments, that their scales are constructed by the multiplication of a unit of length; for workmen generally commit an error in determining the fixed points, on account of the elevation of the liquid upon the stem by capillary attraction; and this error becomes multiplied by each successive repetition. Hence it is easy to perceive the reason why Beaumé's hydrometers, constructed by the same person and with equal care, often differ whole degrees from

HYDROMETER.

each other, when plunged into the same liquid. This fault is the more important, as it affects principally those degrees which are most used. In hydrometers of the decimal system, the graduation is performed by the subdivision of a multiple, and, therefore, any error which unavoidably occurs in measuring the fixed points will be diminished in the ratio of the number of divisions of the interval between them, which certainly constitutes a great advantage, and renders accuracy of workmanship almost certain.

Another defect of the process of Beaumé for graduating hydrometers is, that common salt generally contains impurities; and to obtain it, therefore, perfectly pure, is impractic-

HYDROMETER.

cable, without a degree of chemical knowledge which instrument makers rarely possess. And even if pure salt be obtained and the solution be properly mixed, they are liable to evaporation, which will alter their proportions and density.

The uncertainty of the indications of these hydrometers is established by the fact that tables of comparison with the corresponding specific gravities have been experimentally constructed by several distinguished scientific men, which all vary from each other, owing, doubtless, to the difference of the hydrometers used. The following table gives the results obtained by those whose names are above the vertical columns.

A Table showing the discordant results of different observers, obtained by experimental comparison of Beaumé's hydrometers with specific gravities at 54½° Fahrenheit.

Pèse-acide.				Pèse-esprit.				
Deg.	Franceur.	Delezennes.	Gilpin.	Deg.	Franceur.	Delezennes.	Gilpin.	Holland Pharmacopoeia.
0	1-0000	1-0000	1-000	10	1-0000	1-0000	1-000	1-000
3	1-0201	1-0219	1-020	15	0-9669	0-9655	0-963	0-967
6	1-0411	1-0448	1-040	20	0-9359	0-9333	0-928	0-935
9	1-0630	1-0687	1-064	25	0-9068	0-9033	0-897	0-906
12	1-0857	1-0937	1-089	30	0-8795	0-8751	0-867	0-878
15	1-1095	1-1200	1-114	31	0-8742	0-8696	0-861	0-873
18	1-1343	1-1475	1-140	32	0-8690	0-8643	0-856	0-868
21	1-1603	1-1764	1-170	33	0-8639	0-8590	0-852	0-863
24	1-1875	1-2068	1-200	34	0-8588	0-8539	0-847	0-858
27	1-2160	1-2389	1-230	35	0-8538	0-8486	0-842	0-852
30	1-2459	1-2727	1-261	36	0-8488	0-8435	0-837	0-847
33	1-2773	1-3083	1-295	37	0-8439	0-8384	0-832	0-842
36	1-3103	1-3333	1-333	38	0-8391	0-8334	0-827	0-837
39	1-3451	1-3861	1-373	39	0-8343	0-8285	0-822	0-832
42	1-3818	1-4285	1-414	40	0-8295	0-8236	0-817	0-828
45	1-4206	1-4735	1-455	41	0-8249	0-8188	0-814	0-823
48	1-4615	1-5217	1-500	42	0-8202	0-8141	0-811	0-819
51	1-4951	1-5730	1-547	43	0-8156	0-8094	0-808	0-814
54	1-5510	1-6279	1-594	44	0-8111	0-8017	0-805	0-810
57	1-6000	1-6868	1-659	45	0-8066	0-8001	0-802	0-805
60	1-6522	1-7501	1-717	46	0-8022	0-7956	0-799	0-800
63	1-7070	1-8184	1-779	47	0-7978	0-7911	0-797	0-796
66	1-7674	1-8922	1-848	48	0-7935	0-7866	0-795	0-792
69	1-8313	1-9721	1-920	49	0-7892	0-7823	0-793	0-787
70	1-8537	2-0003		50	0-7849	0-7779	0-791	0-782

Yet the hydrometers of Beaumé, by possessing the advantages of simplicity, cheapness, cleanliness, and adaptation to the liquids for which they are used—solutions of salts, syrups, acids, etc.—and being founded upon known and easy bases of construction, so that they may be made by any workman, have passed into use notwithstanding the well-known imperfections I have mentioned, and to an extent exceeding that of any other hydrometer. This would be surprising, but for the striking contrast of the advantages mentioned, with the correlative disadvantages of complicated structure, high cost, liability to corrosion, limited application, and patented or secret methods of construction, rendering the manufacture a monopoly, which have justly confined other instruments to particular countries or cities.

An instrument which may be accurately, easily, and cheaply made by any workman, is certainly of a nature which should recommend itself. And the decimal hydrometer, which combines all the advantages of the instruments of Beaumé, with a freedom from their defects, and the superiority of being founded upon bases which nature everywhere presents, in which there is nothing arbitrary but the system of counting by tens instead of any other numbers, and the degrees of which are converted into specific gravities by a rule so simple that it may be performed mentally, should certainly be adopted.

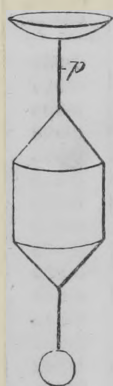
Also, by adopting that scale for Beaumé's hydrometer which seems best entitled to credit for exactness, and drawing it upon the same slip of paper with the corresponding degrees

of the decimal system, instruments may be furnished by tradesmen which will always be accurate, if regarded simply as *pèse-esprits* or *pèse-aires* of Beaumé, and they will cost only the additional labor requisite to draw two scales upon the same paper instead of one.

The stems of hydrometers are sometimes graduated to indicate the pr. cts. of a salt, acid, or other substance contained in aqueous solutions, instead of the corresponding specific gravities. The alcoholometer of Tralles is an instrument of this kind, with reference to which the reader is referred to the article *ALCOHOMETRY*, for more full information. This hydrometer, we are informed, is about to be introduced into the revenue service of the United States, in place of that of Dycas, which is wholly unworthy of confidence.

The invention of hydrometers of *constant volume* is ascribed to Fahrenheit; they have, however, been greatly improved, since his time, by others. These instruments

Fig. 88.



are usually constructed of metal, and of the form indicated by the annexed figure, (88). The bulb being a cylinder terminated by cones, carrying a small dish above and a heavy counterpoise below. The stem which supports the dish is marked at *p*, to which point the hydrometer must be made to sink in a liquid, of which the specific gravity is to be taken by adding weights in the dish. If *w* denotes the weight of the instrument, *x* and *x'* the additional weights respectively required to sink it to the point *p* in any two liquids, then the ratio of *w* + *x* to *w* + *x'* will be that of their specific gravities.

In Nicholson's hydrometer a second dish is substituted for the counterpoise ball, in order that the instrument may be used for taking the specific gravities of solids. For this purpose the weight required to sink the hydrometer in water to the index or fixed point, is first determined; the body is then placed successively in each dish, and weights are added in that above the water, until the instrument is immersed to the same point. If *a* be the observed weight required to sink the hydrometer in water of maximum density, and *s* and *s'* the weights added respectively to that of the solid body when in the upper and lower dish, then *a* — *s* will be its weight, and *s' — s* its loss of weight by immersion; the ratio of which numbers will be the required specific gravity of the solid.

In taking the specific gravities of liquids, attention should always be paid to the temperature, by reason of the changes of volume, which are produced by variations of heat. And whenever accuracy is required, corrections for dilatation both of the liquid and of the hydrometer must be applied, if we would refer the results to any standard temperatures or normal conditions.

HYDROPHANE. See **OPAL**. A massive

and fibrous green mineral, allied to **SERPENTINE**.

HYDROSALTS. Compounds, in the acid or base of which hydrogen is an elementary constituent. In other words, they are salts formed by the union of **HYDRACIDS** with bases. For example the Hydrochlorates, Hydriodates, &c.

HYDROSILICITE. See **KEROLITE**.

HYDROSULPHURIC ACID. See **HYDROGEN, Sulphuretted**.

HYDROTALCITE. *Min.* Resembles talc, and is formed in steatite. Comp. 12 MgO, 2 Al₂O₃ (Fe₂O₃), 3 CO₂, 24 HO. Berzelius thinks it to be a mixture. It may be a compound of Hydromagnesite, with hydrous aluminate and hydrate of magnesia.

HYDROTHIONIC ACID. A term sometimes applied to sulphuretted hydrogen.

HYDROUS ANTHOPHYLLITE. *Min.* In plates and fibres. H. = 2.5. G. = 2.91. White, yellowish, bluish; silky; opaque; sectile. It is a hydrous silicate of magnesia, potassa, and iron. Fishkill and Manhattan Island, N. Y.

HYDROUS MAGNESIA. *Min.* Hexagonal, foliated; H. = 1.5. G. = 2.35. White, pearly, translucent, sectile, flexible in thin leaves. Yields water in a tube, and tests alkaline; is infusible; readily soluble in acids. Rose says he always finds carbonic acid in it. Form. MgO, HO. *Local.* Swinans, Shetland Isles; Hoboken, N. J., the veins sometimes two inches thick; also in Richmond Co. and Westchester Co., N. Y.

HYDROUS MICA. *Min.* Right rhombic, foliated, flexible but not elastic, otherwise resembling mica. Gives water in a tube; partly soluble in muriatic acid, evolving chlorine. According to Morin it is a hydrous silicate of alumina, lime, protoxide of iron, and binoxide of manganese (?) with 14 pr. ct. water. *Local.* Mont Rose, Simplon in the Valais.

HYDROXANTHIC ACID. See **ETHYL, Sulpho-carbonate**.

HYPARGYRITE. See **RUBY SILVER**.

HYPEROXYMURIATES. See **CHLORINE**.

HYPERSTHENE. See **AVGITE**.

HYPO. *Chem.* A prefix equivalent to the Latin *Sub*, under, below;—thus Hypo-sulphuric = S₂O₃ is below sulphuric, SO₃, in the amount of oxygen.

HYPOMARGARYLIC ACID. See **STEARIN**.

HYPOSTILBITE. See **STILBITE**.

HYSSOP, OIL OF. The aromatic, volatile essence of the *Hyssopus officinalis*. Stenhouse has made some recent partial examinations of it, but could not obtain a non-oxygenated oil by treatment with potassa. Its boiling point is 288° rising gradually to 325°.

HYSTATITE. See **TITANIC IRON**.

I.

ICE. Water in a concrete form, this solidity being assumed only at that degree of temperature designated by the thermometer as its freezing point. See **HYDROGEN**.

ICELAND MOSS. See **CETRARIN** and **LICHENS**.

ICELAND SPAR. See **CALCAREOUS SPAR**.

ICE-SPAR. See **FELDSPAR**.

ICHTHYOPHTHALMITE. See **Apophyllite**.

ICHTHYOCOLLA. See **GELATIN**.

ICICA RESIN. Forms small opaque granules or masses of whitish color, and is derived from the genus *Icica* of Guiana. Insoluble in water, but soluble in 55 pts. of cold, and 15 pts. boiling alcohol, and yields no volatile matter. Terpentine also dissolves it. *Scribe*.

Comp. Three neutral resins, differing in solubility and composition; insoluble in alkalies, and non-precipitable from the alcoholic solution by lead or silver salts.

Brean. $C_{80}H_{87}O_3$. Drops in crystals from the cooling solution of the resin in boiling alcohol. Fuses at 315° , and on solidifying again resembles amber.

Icican. $C_{160}H_{137}O_9$. Crystallizes from the slightly evaporated alcoholic liquor from which the *brean* has been separated. Is more soluble in alcohol, but otherwise resembles *brean* in properties.

Colophony. Is similar to ordinary colophony, except in its neutrality. It remains in the mother liquor, from which the two above-mentioned resins have been separated. *Ann. de Chim. et de Phys.* xiii. 166.

IDOCRASE. *Min. Syn.* Pyramidal Garnet, *M. Vesuvian*, *Egeran*, *Loboite*, *Frugardite*, *Wiluite*, *Gökumit*, *Cyprine*, *Xanthite*.

Descrip. Quadratic, presenting most of the forms from fig. 18 to 24, Pl. VIII. $H. = 6.5$. $G. = 3.349 - 3.399$. Color brown, green, rarely yellow; vitreous, subresinous; subtransparent, translucent; streak white; fracture subconchoidal, uneven. Behaves alone and to fluxes similarly to garnet, but fuses with more difficulty with soda. After ignition, it is easily decomposed by muriatic acid. Form. $3RO, SiO_3 + R_2O_3, SiO_3$, in which $RO = \text{lime, magnesia, and protoxide of iron}$. The remarkable agreement of idocrase in composition with garnet, while it differs in crystalline form, has given rise to many analyses; and Magnus always found the oxygen of the silica less than that of the bases, but yet it seems necessary at present to adopt the formula for garnet.

IDRIALIN. Grayish or brownish black, greasy, opaque. Burns by a candle flame, with much smoke and sulphurous acid. Heated to $400^\circ - 460^\circ$, it sublimes mercury and sulphur, and gives off olefiant gas, leaving a porous coal. The main mass of the mercurial ore may be extracted by olive oil, terpentine, creasote, &c. It is insoluble in water, scarcely soluble in alcohol and ether, soluble in oil of vitriol with a blue color. Formula, $C_{42}H_{14} + O$ (*Bödecker*). It occurs in the cinnabar ores of Idria.

IDRYL. *Chem.* An organic principle, C_8H , extracted by boiling alcohol from *Stupp*. The soft, brown mass after the distillation of the alcohol, by solution in concentrated boiling acetic acid, yields the idryl as glittering laminæ, with a slightly yellowish green iridescence. Is nearly inodorous and tasteless; melts at 187° , and solidifies at 174° to an almost colorless, opaque mass; is nearly insoluble in cold, but readily soluble in boiling alcohol, ether, terpentine and acetic acid. Is distin-

guished from *Idrialin* ($C_{42}H_{14}O$), its oxide, by the higher fusing point (313°) of the latter. Idryl also colors sulphuric acid yellow, while idrialin imparts an intense blue. *Bödecker. Annuaire de Chim.* 1846.

IGASURIC ACID. See **STRYCHNINE**.

IGLOITE. See **ARRAGONITE**.

ILLUMINATION. See **GAS**.

ILMENITE. See **TITANIC IRON**.

ILMENIUM. *Chem.* A metal recently found by Hermann in the Yttrilmenite of Siberia and Pyrochlor of Miask. Sym. II. Equiv. 63.

Prep. By igniting the ammonio-chloride of ilmenium in an atmosphere of ammonia, a black, sooty mass, resembling charred sugar, remains. Sulphuric, hydrochloric, nitric, and hydrofluoric acids are without action upon it, even at boiling heat; but it is readily dissolved by a mixture of the nitric and hydrofluoric. When heated in the air it is transformed into ilmenic acid.

Oxide. Precipitates in brown flakes from the muriatic solution of the chloride of ilmenium upon the addition of zinc; absorbs oxygen on exposure, and becomes

Ilmenic Acid. Spec. grav. 4.1 — 4.35. Equiv. 110_2 . It is prepared as follows:—The yttrilmenite is reduced to a fine powder, and this fused with 6 times its weight of the bisulphate of potash; the fused mass is poured out, rubbed to a powder, and exhausted upon the filter with hot water so long as any thing is removed; an impure ilmenic acid, containing sulphuric acid, is left upon the filter. If any tungstic acid had been found by preliminary experiment, the residue is digested with sulphuret of ammonium, and again well washed. After this treatment, the still moist ilmenic acid is evaporated to dryness with a sufficiently large quantity of the bisulphate of ammonia, and finally fused with it to a clear mass. On treating this fused mass with cold water, the whole of the ilmenic acid is deposited in transparent flakes. This precipitate is well washed, formed into a thin paste with water, sulphuric acid added to it, and then evaporated until the excess of sulphuric acid begins to be expelled. The acid residue is mixed with a little water, poured upon a filter, and washed with water as long as the liquid which passes off has an acid taste. A combination of ilmenic with sulphuric acid remains on the filter, which usually no longer colors microcosmic salt; should this not be the case, the fusion with bisulphate of ammonia and evaporation with sulphuric acid is repeated until it is perfectly free from every admixture, when it is heated to redness to expel the sulphuric acid. The ilmenic acid may be prepared in the same manner from the pyrochlor of Miask. *Chem. Gaz.* v. 398.

Prop. When heated assumes a golden tint, but becomes colorless on cooling. Forms salts with bases, some of which are crystallizable. The soda compound, $NaO, 11O_2 + HO$ being the most soluble, is well adapted for the preparation of other salts by double decomposition. When separated from its soda compound by an excess of hydrochloric acid, it is hydrated and falls as a white, diaphanous,

gelatinous precipitate, which dries into opaque, compact pieces.

Chloride of Ilmenium. Is obtained in yellowish, frost-like prisms; attracts moisture on exposure, loses muriatic acid, and becomes hydrated ilmenic acid. It absorbs dry ammonia greedily, with disengagement of heat, and changes into yellow chloride of ilmenium and ammonia.

Sulphuret of Ilmenium. Prepared by heating ilmenic acid to redness in the vapor of sulphuret of carbon. Form. Il_2S_3 . Heated in air it burns with a blue flame, and becomes sulphated ilmenic acid. *Chem. Gaz.* iv. 449. *Jour. für Prakt. Chem.* xi. 457.

ILVAITE. See **YENITE**.

IMPERATORIN. *Chem.* A colorless, styp-tic, crystallizable compound, extracted by ether from the root of the *Imperatoria ostruthium*. Formula $\text{C}_{24}\text{H}_{12}\text{O}_5$; spec. grav. 1.192. Fuses at 167° . Soluble in alcohol, ether, olive oil and essence of terpentine. Sulphuric acid dissolves it, imparting a reddish brown tint to the liquor, and nitric acid gives a yellow shade.

IMPONDERABLES. A term applied to that class of substances which, in being added to or subtracted from a body, neither increase nor diminish its weight. Their influence over chemical phenomena and modus operandi are given under **HEAT**, **LIGHT**, and **ELECTRICITY**.

INCANDESCENCE. The intense glow emitted from a body in which there is an excessive accumulation of heat.

INCINERATION. The reduction of substances to ashes by burning, in order to drive off their destructible portions, and obtain the fixed products.

INCOMBUSTIBLE CLOTH. Cloth saturated with a solution of alum or silicate of potassa, said to be proof against fire. See also **ASBESTOS**.

INDIANITE. See **ANORTHITE**.

INDICOLITE. See **TOURMALIN**.

INDIGO. *Chem. Tech.* A beautiful blue coloring matter, extracted by fermentation from the leaves of the different species of the *Indigofera*. It has also been obtained from the *Polygonum tinctorum*, *Isatis tinctoria*, *Amorpha fruticosa*, *Gymnema tingens*, &c. &c.

The general constituents are ammonia, green extractive and gummy matters, indigo white, blue, brown, and red, indigo gluten, red resin, carbonate of lime, silica, peroxide of iron, and alumina. The proportion of indigo blue varies in the different commercial varieties, and as the coloring power is vested in this ingredient, their value is rated accordingly. That known as Bengal is preferred. The mode of isolating the several components is given in detail at pp. 163, 225, 297, *Franklin Journal*, vol. i., 3d series, and in *Dumas*, vol. viii., pp. 12, 14.

1. **Gluten.** A yellowish transparent varnish, resembling true gluten in its behavior to reagents, but differing therefrom by its solubility in alcohol and incoagulability by boiling.

2. **White.** $\text{C}_{16}\text{H}_6\text{NO}_2$. Isomeric with the cyanide of benzoyle. Is solid, crystalline, fibrous, silky, tasteless, and inodorous. Is heavier

than water, and without action upon litmus paper. Forms yellow solutions with alcohol and ether; is insoluble in water. Does not unite with the weak, but is entirely changed by the concentrated acids. Becomes directly blue by exposure, owing to its powerful affinity for oxygen.

3. **Brown.** Very difficult to obtain in a pure state. A transparent, brown varnish, slightly soluble in water, and forming a neutral solution. It readily forms compounds with acids which are scarcely soluble in water, and unites so powerfully with alkalies, that the resultant solutions give no alkaline reaction.

4. **Red.** A dark red powder, insoluble in water, alkali, or dilute acid. Concentrated sulphuric acid dissolves it with a dark yellow color; chlorine water softens and yellows it, but on exposure it resumes its original character.

5. **Indigo blue.** $\text{C}_{16}\text{H}_5\text{NO}_2$, (*Crum*). Is prepared in the wet way, or by sublimation. In the first case, take 5 pts. of commercial indigo, 10 pts. of green vitriol, 15 of hydrate of lime, and mix and transfer them to a stoppered flask, add 60 pts. of water, and leave to repose for several days. During this interval the protoxide of iron becomes peroxide at the expense of the indigo; this latter is transformed into white indigo, which unites with the lime, forming a soluble compound,—the *cold vat* of the dyers. The clear, yellowish solution thus resulting, is decanted and treated with a slight excess of muriatic acid, which neutralizes the lime and precipitates the indigo colorless. The precipitate is then well washed with pure water, afterwards with boiling alcohol to remove indigo red, and subsequently, after drying, with several portions of boiling sulphuret of carbon to remove the free sulphur which is formed during the precipitation by the acid. By exposure to air at 250°F ., it becomes perfectly dry and blue.

6. To obtain the indigo in crystals, take 4 oz. of the crude article in powder, 4 oz. grape sugar, and mix them with hot alcohol of 75 pr. ct.; transfer to a six-quart bottle, and add 6 oz. concentrated alcoholic ley of caustic soda, and fill the bottle entirely with hot alcohol; when thoroughly shaken leave the whole to repose, then draw off the clear liquid, and expose it to the air. After some time 2 oz. indigo, in copper-colored crystals, will be deposited, and are to be purified by thorough washing, first in alcohol and then in hot water.

7. Crystals of pure indigo may also be obtained by sublimation, it being only necessary, for this purpose, to expose a thin layer of the powdered article in a dish, to a gentle heat, and to catch the sublimate in a head or cone of strong paper. When prepared directly in this manner, from crude indigo, the crystals require to be purified from red by repeated boiling with alcohol.

Indigo blue is volatile, but decomposes at a heat higher than its point of volatilization. Is insoluble in water, alcohol, ether, olive oil, or spirits of terpentine; unacted upon by air, dilute acids, or caustic alkalies. The strong acids, in dissolving it, develop new compounds. It is readily deoxidized by substances

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having a strong affinity for oxygen, provided an alkali or alkaline earth be present, in which case the reduced indigo combines with the strong base.

Action of Sulphuric acid upon Indigo. The resultant products vary with the proportion of acid employed, its strength and length of contact. The stronger the acid, the greater its solvent power. To ensure the solution of the whole of the indigo, 15 pts. of concentrated acid must be used for every part of finely powdered indigo, and the two digested together in a glass flask for several days, at a temp. of 120° to 140° F.; these precautions prevent the formation of

Indigo purple, or sulpho-purpuric acid, $C_{16}H_5NO_2SO_3$, which invariably ensues when the acid is employed too weak, or in too small a proportion. After sufficient digestion, dilute the liquid largely with water, and filter. If the reaction has been perfect, there will be no residue of purple. The filtrate contains *sulphindigotic* or *sulphindilic* acid, $C_{16}H_5NO_2SO_3$, and a small quantity of *hyposulphindigotic* acid. This latter acid is more frequently a result when fuming acid has been used for effecting solution. These acids form compounds with the alkalis, soluble in water, but insoluble in alkaline liquors. To separate them, therefore, add to the filtrate a concentrated solution of acetate of potassa, and again filter upon paper. The liquor passing through should be clear and nearly colorless. To purify the precipitate of sulphate of potassa, it must be several times washed with a solution of acetate of potassa; and to remove the latter, subsequently with common alcohol. The formula of the salt thus obtained is $C_{16}H_5NO_2SO_3, KO$.

Both of these acids form salts with the alkalis, of which the hyposulphindigotates are the most soluble in water, and the ammoniacal salt of the latter soluble in alcohol. To obtain them in a free state, it is only necessary to decompose the potassa salt with acetate of lead, wash the precipitate, and decompose it by sulphuretted hydrogen. By filtration, a yellowish liquid is obtained, which blues in the air, and by evaporation at less than 120° , passes into a blackish blue solid. These acids, in a free state, are yellow, and form solutions with water, which become blue on exposure. The solutions, as well as those of the salts which they form, are turned yellow by nitric acid, chlorine, and bromine.

The sulphindigotic acid dissolved in dilute sulphuric acid gives, in contact with zinc and iron, a colorless or yellowish liquid, which blues by exposure to air, and is a most sensitive reagent for detecting the presence of oxygen in gaseous mixtures.

Indigo purple, *Phæucin*. *Sulphopurpuric acid*. *Phenansulphuric acid*, $C_{16}H_5NO_2SO_3$. Forms the insoluble residue when the solution of indigo is made with too weak or too little sulphuric acid. It is made in the same way as indigo blue, except that but five parts of acid are employed to one of indigo. The precipitate obtained is to be washed with dilute muriatic acid. It is insoluble in acidulated,

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but soluble in pure water, and forms flocculent purple compounds with the alkalis.

Chemic blue. This is the solution of indigo in sulphuric acid, used for dyeing wool, and known as "blue-dye."

A most excellent discharge for indigo blue is caustic soda, potassa, or ammonia in presence of red prussiate of potassa; the latter, $3 KCy + Fe_2Cy_3$, having a great affinity for an additional equiv. of potassium, to convert it into yellow prussiate, $2 KCy + FeCy$, the oxygen at the moment of its liberation removing the coloring matter.

Oxidation of Indigo. Action of Nitric acid. Concentrated nitric acid is so powerful in its action upon indigo as to produce ignition. When diluted it generates the *indigotic* and *carbazotic* acids; if still weaker, it gives rise to *isatin*.

Anilic acid. Syn. Indigotic acid; Nitrosalicylic acid. $C_{14}H_9NO_9 + HO$. Prepared by adding finely powdered indigo in successive portions, as fast as dissolved, to nitric acid of 1.28 spec. grav., diluted with an equal bulk of water, and aiding the reaction with gentle warmth. Two acids form, and for their separation it is necessary to add acetate of lead to the hot solution as long as it gives a brown precipitate. The anilate of lead remains in solution, and subsequently drops in crystals, from which the acid may be separated by means of sulphuric acid. Thus obtained it is in fine white or lemon-yellow needles, of a strong acid taste. It is fusible and volatilizable, more soluble in hot than cold water, unites with the bases, forming yellowish or reddish compounds, of which those with ammonia and with the oxides of lead and silver are soluble and crystallizable.

Carbazotic acid. Syn. Picric acid; Nitropicric acid; Nitrophenic acid; Welter's bitter. Formula, $C_{12}H_2N_3O_{13} + HO$. Is formed in the preceding process, but may be more abundantly obtained by adding portionwise, and with great caution to prevent explosion, one part of indigo in fine powder to 11 pts. of hot nitric acid of spec. grav. 1.43, and after the liquid is quiet, adding, during boiling, more acid, until nitric oxide ceases to be given off. The solution, on cooling, drops the acid in crystals, which require to be purified by solution in potash, precipitation by nitric acid, and recrystallization from water. It is also the product of the action of strong nitric acid upon coumarin, salicin, and several other substances. It is in bright yellow, scaly crystals, of a very bitter taste, readily soluble in hot water and in alcohol and ether; fusible and volatilizable at a gentle heat. Its salts are yellow, and explode when heated. That of potassa being rather insoluble in water and wholly so in alcohol, an alcoholic solution of this acid is used as a reagent for detecting the presence of potassa. The picrate of soda is very soluble, and hence, if the amount of water is not too great, the two alkalis may be distinguished from each other, as the picrate of potassa deposits in minute yellow crystals.

Isatin. $C_{16}H_5NO_4$. Is formed by making 10 pts. of crude pulverized indigo into a thick

pap with water, digesting in a porcelain capsule at a mild heat, gradually adding at the same time, and during constant stirring and boiling, from 6 to 7 pts. of nitric acid. The indigo is transformed, the liquid becomes yellow, and contains isatin and brown matter. Dilute the whole largely with water, boil, and rapidly filter the hot liquid. The isatin deposits after a time in reddish powder, which is to be washed with slightly ammoniacal water, and subsequently with boiling water or alcohol.

Indigo may also be oxidized into isatin by means of chromic acid eliminated from a mixture of bi-chromate of potassa and sulphuric acid, mixed with 20 or 30 pts. of water. Heat is to be discontinued as soon as the blue color is destroyed.

Isatin is in brilliant reddish crystals, and readily forms solutions with hot water and alcohol, which stain the skin, and impart an unpleasant odor. It is inodorous, unalterable by exposure, and in volatilizing gives off irritant vapors. Alkalies change it into *Isatic acid*, $C_{16}H_6NO_5$; hydrosulphuret of ammonium into *Isatyde*, $C_{16}H_6NO_4$; chlorine into *Chlorisatin*, $C_{16}H_4ClNO_4$, which forms orange crystals and *Bichlorisatin*, $C_{16}H_3Cl_2NO_4$, in hyacinth crystals, rather more soluble in water and alcohol than the former; ammonia into *Imesatin*, $C_{16}H_6N_2O_2$, *Imasatin*, $C_{32}H_{11}N_3O_6$, *Imasatinic acid*, $C_{32}H_{11}N_3O_6 + HO$, and *Amasatin*, $C_{16}H_7N_2O_3$.

Action of Chlorine upon Indigo. There is no reaction between chlorine and indigo in a dry state; but when the gas is passed through a paste of the latter at a low temperature, decomposition ensues, the mass becomes yellow, and new compounds are formed without disengagement of carbonic acid or any other gaseous product. Among these products are *Chlorisatin* and *Bichlorisatin*. By distillation of the mass a white crystalline sublimate (*Chlorindopten*) results, consisting of *Chlorindatmit* and *Chlorindoptenic acid*. Erdmann.

Chlorindatmit. $C_{12}H_4Cl_3O$. Syn. *Trichloranilin*. Sublimes as a white mass when chlorindopten is distilled with carbonate of potassa. It is also derived, according to Hoffmann, from anilin, $C_{12}H_7N$, by the replacement of 3 equivs. of hydrogen by 3 equivs. of chlorine. It is fusible and volatile, has a fennel-like odor, and a neutral reaction.

Chlorophesenic acid. Syn. *Chlorindoptenic acid*. $C_{12}H_2Cl_3O + HO$. The potassa salt remaining in the retort after the distillation of the chlorindatmit, when acted upon by hydrochloric acid, yields this acid as a white flocculent precipitate, of a nauseous smell, crystallizable, and forming a lemon-yellow, insoluble salt, with oxide of silver.

Action of Bromine upon Indigo. Bromine, under the same circumstances, reacts similarly to chlorine upon indigo, and produces an analogous series of compounds.

Action of Alkalies upon Indigo. Potassa, in reacting upon indigo, produces several compounds varying in their properties with the process employed.

Chrysamilic acid. Add indigo in powder to boiling potassa solution, of spec. grav. 1.45,

and evaporate the resultant deep red liquid. The crystalline mass which forms on cooling when exposed, in aqueous solution, deposits blue indigo. By neutralizing the greater part of the potassa with an acid until a bluish green precipitate ceases to be formed, and then adding acetic acid to the clear golden solution obtained by filtration, *Chrysamilic acid* is thrown down. (*Fritzsche*.) In this state it is a brownish precipitate, but becomes yellow when purified by solution in ether and evaporation. From its boiling solution in dilute mineral acids, bluish black crystals of unknown composition are deposited, and *Anthranilic acid* remains in the liquid.

Anthranilic acid. $C_{14}H_6NO_3 + HO$ (*Fritzsche*). Is isomeric with *Salicylamide*. To the alkaline solution, made as above directed, add finely powdered peroxide of manganese until the liquid, when diluted and exposed to air, no longer yields blue indigo. Anthranilate of potassa remains in solution with free potassa. To purify the crystals, they must be dissolved in the least quantity of water possible, and neutralized exactly with dilute sulphuric acid. The mixture evaporated to dryness is treated with boiling alcohol, which dissolves out the anthranilate and leaves the sulphate of potassa. Acetic acid being added in excess to the alcoholic solution, throws down the impure acid in orange-colored flocculæ. To purify, combine it with lime, recrystallize the lime salt from a solution decolorized by bone-black, and separate the acid anew by a slight excess of acetic acid.

Anthranilic acid is in brilliant yellowish white plates, soluble in alcohol and ether, and sparingly in cold water. Its compounds with lime and with silver are both soluble and crystallizable. When gently heated it fuses and sublimes, but by a stronger heat is converted into anilin and carbonic acid.

Anilin, (*Hoffmann*). Syn. Crystalline, (*Unverdorben*); Benzidam, (*Zinin*); Kyanole, (*Runge*). Formula $C_{12}H_7N$. Is formed under a variety of circumstances:—1st, By the action of potassa upon indigo or isatin. 2d, By the distillation of anthranilic acid. 3d, By the action of sulphuret of ammonium or of an alcoholic solution of potassa upon nitrobenzine. 4th, By the distillation of nitrobenzoin or salicylamide with lime. 5th, By the destructive distillation of coal and of indigo. 6th, It is also a frequent product of the decomposition, at high temperatures, of nitrogenous substances.

Prep. 1. By dissolving powdered indigo blue, with heat, in very strong potassa ley, and heating the mass to dryness. 2. Hoffmann obtained it from the oil of coal tar, by treating it with hydrochloric acid to remove the basic oils which are contained in the lower stratum of the two thus formed, after twelve hours. The lower stratum is to be agitated with an additional quantity of tar oil, and after the hydrochloric acid has become neutralized, the solution is treated with an excess of milk of lime, and distilled. A milky liquid first condenses, and contains impure anilin and leukol, (quinolein), to purify which the mixture must be again neutralized by hydrochloric acid and then treated with ether, which dissolves the

INFUSION.

non-alkaline oils, leaving the alkaloids in the aqueous stratum, swimming on the top. The two bases are neutralized by an alkali, and subjected to distillation. That portion which passes over at 360°, contains the anilin, which may be purified by converting it into oxalate and crystallizing this salt repeatedly from absolute alcohol, and finally decomposing the solution by distilling with potassa.

Prop. A colorless, oily liquid, of spec. grav. 1.020, having a vinous odor, and burning, aromatic taste. It is highly refractive; boils at 360°, and is not congealed by a cold of -4°; mixes in all proportions with ether, alcohol, wood-spirit, acetone, aldehyde, sulphuret of carbon, the fat and essential oils. Its aqueous solution does not affect litmus or turmeric paper, but greens the coloring matter of the *dahlia*. It dissolves, whilst hot, sulphur, phos-

Hypothetical radical $C_{12}H_5$ Phenyl.
 Carboic acid $C_{12}H_5O, HO$ Hydrated oxide of phenyl.
 Chlorindoptenic acid..... $C_{12} \left\{ \begin{smallmatrix} H_2 \\ C_3 \end{smallmatrix} \right\} O, HO$ Chlorophenismic acid.
 Chlorinized chlorindoptenic acid .. $C_{12}Cl_3O, HO$ Chlorophenusic acid.
 Nitropicric, or Picric acid $C_{12} \left\{ \begin{smallmatrix} H_2 \\ 3NO_2 \end{smallmatrix} \right\} O, HO$ Nitrophenismic acid.
 Anilin, $C_{12}H_7N =$ $C_{12}H_5 + NH_2$ Phenylamide, or Amaphenase.

"In this view, anilin is composed of phenyl and amide; and, whether this be so or not, it is certain that every one of the compounds in the above table may be converted into chloranile by the action of chlorate of potash and hydrochloric acid, which, taken along with their common origin in indigo, would indicate a close relation among them all." *Turner, [New Organic], p. 1222.*

Muriate of Anilin. Crystalline; soluble in water and alcohol.

Oxalate of Anilin. Crystallizes in long needles from its aqueous solution. *Dumas*, vol. viii., p. 8. *Chem. Gaz.* iii. 108, 136, (*Hoffmann*). *Laurent, Erdman's Journ. für Prakt. Chem.*, 28, 337, 204, 198, 193.

INFUSION. *Chem. Pharm.* Bodies, particularly vegetable and other easily penetrable substances, are infused by being drenched with boiling water, and then left to cool. The liquor which contains the soluble portions of the matter acted upon is called an infusion. This process of exhaustion applies to all substances which contain volatile or other principles that would be altered by prolonged heat. The vessel in which the operation is performed should be covered.

INK. The black or colored medium through which thoughts and words are permanently expressed upon paper and other plane surfaces. Inks differ in consistence and composition according to mode of application.

Writing Inks. Under this head are comprised all those fluids which are used with the pen, for writing upon paper. They are of various colors.

Black Ink. The desiderata in this article are fluidity, intensity, and durability of color, and freedom from corrosive action. These are to be accomplished by a proper apportionment of materials and intelligent and careful manipulation. The basis of black ink are galls and iron salt, and their efficacy depends

INK.

phorus, camphor, and resin; coagulates albumen, and forms crystallizable salts with the acids, which on exposure gradually become rose-red, and ultimately brown.

This base is analogous to ammonia, forming, like it, double salts, with bichlorides of mercury and of platinum. It is very oxidable, and hence the facility of distinguishing it by its property of forming a deep, but fugitive blue, with a solution of chloride of lime. Nitric acid converts it into picric acid; chlorine into chlorophenismic acid and chlorindatmit; bromine into bromaniloid, which transformations indicate that anilin belongs to the phenyl series.

"The following table will illustrate the relation of anilin and its derivatives to the hydrate of phenyl:—

upon their chemical state. The iron salt should be a mixture of a proto and peroxy base, because if it is wholly the former, the tannin of the galls has no coloring effect;—if entirely of the latter, the presence of much gallic acid generates a compound which, owing to the decomposition of the acid, is gradually decolorized by the reduction of the iron to a protoxide. The solution of galls should be perfectly clear and free from sediment, and that as little gallic acid may be present as possible, the decoction should be used soon after it has been made. The suspension of the impalpable precipitate is effected by gum. The ink should be allowed to ripen for some time, so that the insoluble precipitate which is thrown down at first by the small portion of gallic acid, may be redissolved in the excess formed from the tannin by exposure. Logwood, sumach, oak bark, and similar astringents are not good substitutes, for, besides being comparatively poor in gallotannic acid, they contain other tannic acids and coloring matters which debase the rich blue-black given by galls alone. The suspension of the precipitate depends on a state of semi-solution, which requires investigation.

Ink stains are tanno-gallates of iron, readily removable by oxalic and citric acids, or chloride of lime, which effects their decomposition and the solubility of the iron basis; after-rinsing in water, removes all traces of spots. Faded ink or iron-mould can be restored to its former black color either by an infusion of galls or a muriatic acidulated solution of prussiate of potash.

Below are several valuable recipes:—

	Aleppo Galls.	Cop-peras.	Gum.	Water.
	Lbs.	Lbs.	Lbs.	Galls.
Superior Black Ink..	12	4	3½	18
" Exchequer .	40	9	10	45

The galls should be bruised and exhausted

by three consecutive boilings, each time diminishing the quantity of water, and supplying, by fresh addition, any loss by evaporation. The copperas and gum in solution are added to the strained decoction of galls whilst both are yet warm, and the whole allowed to settle for weeks, and then drawn off from the sediment. A few cloves, or some drops of creasote prevent any tendency to mouldiness.

Japan Ink. Made as the above, but with the copperas highly peroxidized by roasting. This ink is intensely black when written with, but the color does not retain its depth or lustre. The addition of sugar to this or the before-mentioned writing inks, renders them *Copying inks*.

Blue Ink. Prepared by thoroughly triturating perfectly pure Prussian blue (6 pts.) and oxalic acid (1 pt.) with soft water. A little gum is added to prevent its spreading upon the paper. A most brilliant, permanent, and uncorrosive blue fluid is also made by dissolving basic Prussian blue in slightly mucilaginous water. Written with upon cloth, saturated with alum solution and then dried, it gives an indelible mark.

Red Ink. Hensler's recipe is:—2 oz. best Brazil wood, $\frac{1}{2}$ oz. pulverized alum, and $\frac{1}{2}$ oz. crystals tartar, are boiled with 16 oz. distilled water to one half. Half an ounce of gum Arabic is dissolved in the strained liquor, and finally a tincture made of $1\frac{1}{2}$ drachms of cochineal and $1\frac{1}{2}$ oz. alcohol of spec. grav. 0.839, mixed with it.

A very brilliant red can be made with the following proportions:—

Brazil wood	2 oz.
Muriate of Tin.....	$\frac{1}{2}$ drachm.
Gum Arabic	1 drachm.
Water (boiled down one half) .	32 oz.

A solution of carmine in an excess of ammonia makes a beautiful but fugitive red ink.

Indelible Inks. Used for marking on linen, but improperly so called, because they can readily be discharged by ether, chlorine, or ammonia, and without injury to the fabric, provided it is rinsed in water immediately after the application.

The usual preparation is a solution of 1 oz. nitrate of silver in 4 oz. water, which when cold is thickened with a little mucilage. The part to be written on is first moistened with carbonate of soda liquor, and then dried.

The marking ink used without a soda preparation is an ammoniated solution of nitrate of silver thickened with a little mucilage.

A true, black, indelible ink can be made by suspending 10 grs. best lamp black and 2 grs. of indigo in 4 oz. of acetic solution of pure gluten, of the strength of wine vinegar. This ink is inappropriate for marking on linen, as it does not resist mechanical force or rubbing.

Indian Ink. Purified lamp black of the finest quality made into a paste with glue, and then moulded into sticks.

Sympathetic Inks. These have no practical use. They are made of metallic solutions and mixtures, which when written with give no apparent mark until after the paper is heated.

Printing Inks. There also are the ordinary printing ink, copper-plate, and lithographic ink. The desirable properties of the first named are depth and brilliancy of color, pliability in working, freedom from clamminess, and facility of removal from the types without the use of ley. Below are the ingredients and their proportions for good book ink:—

Best clear linseed oil (old)	$1\frac{1}{2}$ galls.
Rosin (powdered).....	6 lbs.
Dry brown soap, in shavings... ..	$1\frac{1}{2}$ lbs.
Indigo and Paris blue, each	$2\frac{1}{2}$ oz.
Best lamp black	5 lbs.

The oil must first be boiled and burned to the consistence of a thick varnish; whilst still hot, and during constant stirring, it should receive gradually both the rosin and soap in consecutive order. The coloring matters thoroughly mixed are then to be intimately incorporated with a crutch. When the ink has ripened for a week it should then be ground in "Bogardus eccentric mills." By boiling the oil less thick and adding more rosin and consequently soap to counteract the binding effects of the latter, a cheaper ink is obtained.

For a very superior black ink, Savage has proposed as follows:—

Balsam copaiva	9 oz.
Lamp black of the finest quality .	3 oz.
Paris blue	$1\frac{1}{2}$ oz.
Indian red	$\frac{1}{2}$ oz.
Dry rosin soap.....	3 oz.

The colored inks are made with the above varnish, by substituting white soap for the yellow, and a pigment of the desired shade for the black coloring mixture.

Lithographic Ink. An encaustic with which lineaments or traces are marked upon lithographic stone, and are again transferred to paper by means of a printers' ink with which it may be covered. Lasteyrie's approved composition is as follows;—

Dried tallow soap	30 pts.
Mastic in tears, and soda, each .	30 pts.
Shellac	150 pts.
Lamp black.....	12 pts.

When the ink is to be used, it must be rubbed down with water to the required consistency and depth of shade.

Copper-plate Ink. Prepared solely with thickly boiled nut or linseed oil, and finely powdered Frankfort black.

INOLITE. See **CALC SPAR.**

INSTRUMENTS, CHEMICAL. See **LABORATORY,** and **Morfit's "Chemical and Pharmaceutical Manipulations."**

INTESTINAL CONCRETIONS. Consist mostly of earthy phosphates and fatty matters. See **BEZOAR.**

INULIN. *Syn.* Alantin, Menyanthen, Elecampin, Dahlin, Datescin. A variety of starch existing also in the tubercles or bulbs of several of the synantherous plants which do not yield starch. It is extracted by boiling water, and is deposited by the concentrated decoction, either in minutely spheroidal grains, or as a brittle, crystalline, white mass. It is insoluble

IODIC SILVER.

in alcohol and cold water, but with hot water forms a liquid, non-gelatinous solution; spec. grav. 1.336; iodine colors it slightly brown; dilute sulphuric acid aided by heat converts it into grape sugar more readily than starch; nitric acid transforms it into malic and oxalic acids without a trace of mucic acid. Heated a little above 212° , it fuses with the loss of water into a gummy mass, soluble in water, and yielding to alcohol a brown matter. According to Parnell, when dried at 212° it consists of $C_{21}H_{21}O_{21}$, and two of its compounds of oxide of lead are thus constituted $C_{24}H_{21}O_{21} + 5 PbO$ and $C_{24}H_{18}O_{18} + 3 PbO$.

Inulin has been the subject of analysis by several chemists, the difference in whose results are attributed by Wosskressensky to its impurities as usually prepared, and not, as Crookenit announced, to the variety of plant from which it was obtained. Mulder advances the formula $C_{12}H_{10}O_{10}$, but according to Wosskressensky inulin may be prepared of constant composition, and after many analyses announced its composition to be $C_{24}H_{19}O_{14}$ (*Bull. de l'Acad. St. Pet. v., No. iii., p. 36.*) This chemist places the deficiency of carbon in other analyses to the rapid oxidation of the inulin during the process.

IODIC SILVER. *Min.* Foliated, soft, flexible plates, white, yellowish green, resinous, translucent, streak submetallic. It fuses readily, colors the flame purplish, and leaves a globule of silver. Soluble in strongest nitric acid. It contains silver, lead, iron, iodine, and sulphur. It occurs at Abarradon, Mexico.

IODINE. *Chem.* The name from *iov*, the violet, in allusion to the color of its vapor. Discovered in 1812, by Courtois. It occurs in a few minerals, iodic silver and mercury; in most salines, and in minute quantity in sea-water, as alkaline iodides; in animals and plants living in the sea, or growing on the sea coast; in minute quantity in turf and coals.

Prep. It is best obtained from the mother liquor of salines or sea-water after the separation of salt, &c., by several methods. 1. By heating this liquor with binoxide of manganese and oil of vitriol, and subliming the iodine. (*Wollaston.*) 2. By evaporation with $\frac{1}{10}$ of manganese to dryness, heating it to below ignition, dissolving in water till it shows 36° Beaumé, and passing chlorine through the solution until iodine ceases to precipitate. (*Barruel.*) 3. Precip. the mother liquor by blue vitriol, draw off the liquor from the subiodide of copper, precip. it again with blue vitriol and iron filings, wash over the precip. from the filings, and separate it quickly from the solution. The two portions of subiodide are then mixed with 2 or 3 times as much manganese and enough oil of vitriol to make a stiff paste, and heated to sublime the iodine; or the mixture, without oil of vitriol, is heated highly. (*Soubeyran.*) 4. From the mother liquors of kelp-soda. The liquors are concentrated to crystallize out foreign salts; the residue acidulated with sulphuric acid until it reddens litmus, and a very slow current of chlorine passed through the clear liquor, which is agitated. When the liquor

IODINE.

loses its red color, a portion of it is tested by a strong solution of chlorine; and when it ceases to thicken by this addition, the whole is left to settle, when the iodine collects at the bottom in brown flakes. Bromine is extracted from the residuary liquor by distilling it with manganese and sulphuric acid. (*Couturier.*) The iodine obtained by any of these processes may be purified by grinding it with a little water, drying between paper-folds, and resubliming; or by solution in alcohol, filtration and precipitation by water.

Prop. At ordinary temperatures it is a blackish gray, crystalline solid, with a metallic lustre, transmitting red light in thin flakes, very soft and pulverizable, spec. grav. = 4.95; fusible at 225° , congealing again to a crystalline mass; rising in a deep violet vapor at about 350° ; spec. grav. of vapor 8716. Its odor resembles that of chlorine; its taste is pungent and styptic; it is poisonous; soluble in 7000 pts. water (in 500 water at 68°), in much smaller quantities of alcohol and ether, with a brown color; dissolves in naphtha and bisulphuret of carbon with a violet color.

Tests. A boiled and cooled solution of starch is the best test for free iodine; and to set it free a little nitric acid is added to the liquid; 1 pt. iodine is recognised in 450,000 pts. water; in larger quantities, its violet vapor is sufficiently characteristic. Dr. Cantu's process detects both iodine and bromine in exceedingly minute quantities. The water is evaporated to half its bulk, a slight excess of pure carbonate of potassa added, the liquid boiled, cooled, filtered, and evaporated to dryness, avoiding too high a heat. It is then powdered and extracted by alcohol of 0.953, the clear liquid evaporated, the residue heated to low redness, treated with a slight excess of acetic acid, and again evaporated to dryness. It is then dissolved in the smallest quantity of water with a few drops of a weak solution of starch, and a little of the test-liquor poured over it (test-liquor = 10 pts. oil of vitriol and 1 pt. nitric acid of 25° B.). Two zones appear in the liquid, one of yellow (bromine) below one of blue (iodine). Cantu in *Chem. Gaz.*, vi. 395.

Sym. I. Eq. 126, (789.75, *Eerz.*).

Sulphate of Iodine. A small quantity of anhydrous sulphuric acid forms with iodine a brown liquid, a larger amount a blue, and still more acid a green liquid.

Iodohydric acid. Syn. Hydriodic acid. Iodine will directly combine with hydrogen at a high temperature; it will extract hydrogen from most of its compounds; it will even decompose water in presence of zinc, iron, phosphorus, sulphurous and arsenious acids, and protosalts of tin, these bodies being oxidized.

Prep. 1. Decompose iodide of barium by the equiv. of sulphuric acid. 2. Distil phosphorus, iodine, and water. 3. Pass sulphuretted hydrogen through a solution of iodine in water or alcohol. 4. The gas is obtained by distilling 1 pt. phosphorus, 20 pts. iodine, 14 pts. iodide of potassium, and a little water, at a gentle warmth.

Prop. Form. HI, containing 99.21 pr. ct. iodine. A colorless gas, resembling muriatic

IOLITE.

acid in odor and taste; spec. grav. = 4402.4; reddens litmus. It dissolves largely in water, fumes when concentrated, boils at 260°, decomposes by exposure to the air, losing hydrogen and depositing crystals of iodine. It dissolves iodine, possibly forming hydriodic acid = HI_2 .

Iodides. Are formed directly by iodine and metal; by metallic oxide and iodohydric acid; by precipitation with a soluble iodide. They are colorless, and of various shades of red and yellow, generally soluble in water; bear heat unchanged (except gold, platinum, and palladium), but exposed to the air at the same time change into oxides; their solution is generally decomposed by evaporation (except the alkaline); decomposed by chlorine; oil of vitriol and strong nitric acid color the solutions yellow and brown; they dissolve iodine, forming dark reddish brown solutions. In some, a portion of iodine may be replaced by oxygen, forming oxyiodides.

Iodic acid. Form. IO_3 . It is formed by alkali, iodine, and water, $6\text{KO} + 6\text{I} = 5\text{KI} + \text{KO}, \text{IO}_5$; by the action of strong nitric acid on iodine; by the action of chlorine on iodine and water, with or without alkali; by the oxides of gold, silver, and mercury. It is prepared by digesting iodine with nitric acid of 1.55 spec. grav., until all the iodine disappears; or by decomposing iodate of soda or baryta by sulphuric acid, and crystallizing.

Prop. It forms white, hexagonal plates, is very acid; dissolves readily in water, less so in acid water, partly precipitable by alcohol; it is decomposed by heat into iodine and oxygen, and explosively by charcoal, sulphur, rosin, sugar, and finely powdered metals.

Iodates. Are formed by the direct union of the liquid acid and oxides; or by the alkalies and iodine. They are generally crystallizable, with 1, 2, or 3 equivs. acid; the alkaline readily soluble, the others little or not at all soluble; some of them are somewhat explosive when heated with combustibles, but less so than the chlorates or nitrates.

Periodic acid. Form. IO_7 . *Prop.* From periodate of soda dissolved in dilute nitric acid, by precipitating with nitrate of silver, dissolving the precip. in hot dilute nitric acid, and evaporating to crystallize the periodate of silver. By treating this with water, one half of the acid is dissolved out. It is similarly procured from the soda salt by a little warm, dilute nitric acid, precipitating with nitrate of lead, and decomposing this precip. by an exact quantity of sulphuric acid (better a little less). The solution of periodic acid, by careful evaporation, yields the crystallized hydrated acid.

Prop. Colorless crystals, fusing without decomposition at 266°; easily decomposed by oxidable substances and many organic bodies. *Periodates* are neutral and basic, insoluble or difficultly soluble in water, more soluble in dilute nitric acid, readily in alcohol and ether; easily decomposed by heat.

IOLITE. See CORBIERITE.

IOLITE, HYDROUS. See FAHLUNITE.

IPEACACUANHA. The root of the *Cephalis Ipecacuanha*. Pelletier's analysis of the brown, annulated variety, gave—

IRIDIUM.

	Cortex.	Meditullium.
Emetin	16	1.15
Odorous fatty matter	2	trace
Wax	6	—
Gum	10	5.00
Starch	42	20.00
Ligneous matter	20	66.60
Non-emetic extractive	0	2.45
Loss	4	4.80

Bucholz's analysis of the same is to be found in *Gmelin*, ii. 1281.

The fatty matter is extracted by ether, being soluble in it and alcohol, to both of which it imparts a yellow color. It consists, 1st, of the fugacious, volatile, odorant principle of the root, and 2dly, a fixed, inodorous, fatty matter.

Emetin. $\text{C}_{35}\text{H}_{21}\text{NO}_9$ (?). Exists also in the *Psychotria emetica* and *Richardia scabra*. A whitish, inodorous, slightly bitter powder, unalterable in the air, fusing at 122°, and decomposing a few degrees beyond that point. Slightly soluble in cold water, more so in boiling water, readily in alcohol, and scarcely in ether and the essential oils and caustic alkalies. Nitric acid converts it into oxalic acid. Its combinations with the other acids are slightly acid, and difficultly crystallizable.

IPOMÆA ORIZABENSIS. The fusiform, or male JALAP. The resin of this root differs from that of the *I. Ipomœa*, is simple and entirely soluble in ether. Kayser calls it *Pararhodoretin* = $\text{C}_{42}\text{H}_{34}\text{O}_{18}$; and it is distinguished, as is the jalap resin, by the characteristic carmine color of its solution in oil of vitriol, which after some hours deposits a brown smeary resin.

IRIDIUM. *Min.* Metallic particles found in the platinum sand. Svanberg found some containing 76.8 iridium and 19.64 platinum. G. 22.65. (*G. Rose*.) The heaviest body known. *Local.* Nische-Tagils, Siberia.

IRIDIUM. Chem. (*igs, rainbow*, in allusion to its colored compounds.) Discovered in platinum sand, together with osmium, by Tennant, in 1804, although their existence was previously surmised by Descotils, Fourcroy, and Vauquelin. Some pieces of native iridium have been found in the sand, but it is also associated with osmium, platinum, &c., and as an oxide in *IRIT*. Iridium is obtained from the platinum sand in the same series of operations employed for the other platinoid metals. See PLATINUM. The metal may be obtained in powder or as sponge, by igniting most of its compounds. The powder is gray, becoming silver-white by friction; or may be obtained in brighter spangles by ignition of KCl , IrCl_2 . It is uncertain whether the pure metal is fusible, although Children with a galvanic battery, and Bunsen with the hydroxygen blowpipe, fused it to a porous metal. Dr. Hare fused a small quantity which I had prepared, into a somewhat rounded mass, exhibiting projecting points, as if an infusible substance were contained in it, unless as Bunsen asserts, it is crystalline. (*J. C. B.*) Sym. Ir. Eq. 99, — (1233.5 (*Berz.*), O = 100).

Oxides of Iridium. 1. *Oxide of Ir.* IrO . Formed by boiling dry protochloride of iridium with concentrated potassa, is a black powder. Its hydrate, formed by precipitating the double

protochloride of iridium and potassium or sodium by carbonate of potassa or soda, is greenish gray, soluble in alkali with a greenish yellow color, in acids with a greenish gray color. It does not lose its oxygen at a red heat.

2. *Sesquioxide of Ir.* Ir_2O_3 . Obtained by fusing bisulphate of potassa with the metal, or by heating bichloride of iridium and potassium with twice as much carbonate of potassa or soda, at not too high a heat. A blue black powder, losing its oxygen only below the fusing point of silver. The hydrate is obtained similarly to the hydrate, (1.) from the sesquichloride alone, or its combination with alkaline chloride. The hydrate dissolves in acids with a dark brown or purplish color; it also unites with alkalis. There is a blue oxide, probably a combination of the two preceding oxides.

3. *Binoxide of Ir.* IrO_2 . Known only in its salts, which dissolve with a brownish red color, and are formed from the salts of the lower oxides by boiling them in the air or with nitric acid. 4. A *trioxide*, IrO_3 , is also formed from the terchloride by alkali, but is only known in union with alkali or muriatic acid.

Sulphurets. 1. *Sulphuret of Ir.* Formed by precipitating an oxide (1.) salt with sulphuretted hydrogen, or by igniting a higher sulphuret in a close crucible. It is easily soluble (if precipitated) in nitric or nitro-muriatic acid, as sulphate, and readily in sulphuret of potassium. 2. The *sesquisulphuret*, formed from a sesqui-salt by sulphuretted hydrogen; behaves similarly to 1. 3. *Bisulphuret*, formed by igniting iridium with sulphur and carbonated alkali, or by precip. bichloride with sulphuretted hydrogen; behaves similarly to the preceding. 4. The *tersulphuret*, formed from terchloride double salts, is similar to the preceding.

Carburet. Carbon unites with iridium to a compound, consisting of IrC_4 . A phosphuret also exists, which by ignition in the air becomes phosphate of the oxide.

Haloid salts. 1. *Chloride of Ir.* IrCl . Formed by passing chlorine over finely-powdered iridium, at a low red heat, as a dark olive-green powder; it is insoluble. By decomposing it with potassa, dissolving the oxide in muriatic acid, and evaporating, the same salt is obtained of a yellow color, soluble in water.

2. *Sesquichloride.* Obtained by igniting iridium with saltpeter, extracting the alkali by nitric acid and then by water, dissolving in muriatic acid, and evaporating, is a black mass, soluble in water with a color from dark brown to yellow, according to the concentration.

3. *Bichloride of Ir.* IrCl_2 . Formed by digesting the preceding with nitromuriatic acid, gives a similarly colored solution, which tends to form sesquichloride by boiling, and is wholly so converted by evaporating its alcoholic solution. 4. Chloride of Ir. and Potassium, KCl , IrCl , made by directly mixing the salts, gives, by careful evaporation, a dark green, crystalline mass, insoluble in alcohol. 5. The sesquichloride salt, 2KCl , Ir_2Cl_3 , formed by adding to the sesquichloride less chloride of potassium than is requisite to make the whole iridium into the double salt, and by gentle evaporation, is brownish black, amorphous, permanent in the air, soluble in water, not in alcohol. 6. The

double bichloride, KCl , IrCl_2 , obtained by passing chlorine over a mixture of fine iridium and chloride of potassium at a low red heat, extracting chloride of potassium from the mass by small quantities of cold water, then the chloride salt by boiling water, filtering, and evaporating with the addition of a little aqua regia; forms dark red, regular octahedral crystals, which by ignition change into sesquichloride, and by a higher heat yield scales of iridium, with a metallic lustre, (*Wöhler*); slowly soluble in cold, readily in boiling water; insoluble in saturated solutions of chloride of potassium and various salts, and in alcohol, which last wholly precipitates it. Being isomorphic with the corresponding salt of platinum, it crystallizes with it. The reaction of nitrate of silver upon this double salt is recommended as a test for iridium, by Claus. At the beginning of the action, an indigo-blue precipitate appears, which soon loses its color; the precip. is 3AgCl , Ir_2O_3 . 7. The trichloride, 3KCl , IrCl_3 , is obtained by treating iridosmin with saltpeter, distilling it with aqua-regia, dissolving the residue in the retort with water, evaporating the filtrate to dryness, and extracting with successive portions of water; the first solutions, slightly colored, contain chloride of potassium; the following are rose-red, and the last yellow, from the double bichloride. The rose-red solutions are evaporated to dryness, powdered, treated with alcohol of 0.84, and the brown residue dissolved in water and evaporated to crystallize. By transmitted light, they appear as ruby-red, rhombic prisms, whose solution by repeated evaporation leaves green chloride of iridium. 8. The proto, sesqui, and bichloride of iridium and sodium are similar salts, similarly made, and more soluble in water and alcohol; the bichloride double salt crystallizes with 6 HO . 9. Chloride of iridium and ammonia precipitates as a greenish powder from solutions of the protochloride double alkaline salts, by adding ammonia; form. NH_3 , IrCl . The chloride with ammonium, NH_4Cl , IrCl , formed from the sesquichloride of iridium and salammoniac, gives a green solution of this salt, while the bichloride double salt precipitates. The sesquichloride is formed like that of potassium, 5. The bichloride, NH_4Cl , IrCl_2 , precipitates as a dark red powder, by adding salammoniac to a strong solution of sesqui or bichloride, or of the bichloride with sodium. It forms very dark-red octahedra, soluble in 20 pts. cold water, colors 40,000 pts. water yellow.

Oxysalts. Iridium has a feeble affinity for acids. The sulphates are formed by the action of nitric acid on the sulphurets. Nitric acid dissolves the oxide with a greenish color, which passes into a purple.

Alloys. Iridium unites with tin and lead to white, slightly malleable alloys, at a bright red heat; with copper to a reddish white, malleable alloy; with sodium-amalgam, to a pasty amalgam; with gold to a yellow, ductile alloy; with an equal weight of platinum to a brittle, but weldable alloy; with 10 pts. platinum a malleable alloy.

IRIDOSMIN. *Min.* Hexagonal plates, cleav

ing parallel to end-plane. Generally irregular, flattened, metallic grains, of a tin-white or light steel-gray color, of extreme hardness. $G = 19$ to 21.118 . Some varieties with much osmium, give off the chlorine odor of osmic acid, by the blowpipe alone; others when ignited with saltpeter; best decomposed by mixing with salt and passing chlorine over it, to form the soluble, double chloride. Form. of 3 varieties, IrOs , IrOs_3 , IrOs_4 . *Local.* Minas Geraes, Brazil; Newiansk, Katharinenburg, Nischne-Tagil, Siberia.

It is employed to point the gold pens now in general use.

IRIT. *Min.* Found coating pieces of platinum, in the Ural, as black, shining scales; magnetic; spec. grav. = 6.056 ; evolves osmic acid by ignition with saltpeter. Probable form. FeO , $3\text{Ir}_2\text{O}_3 + \text{FeO}$, $\text{OsO}_2 + 3(\text{FeO}, \text{Cr}_2\text{O}_3)$.

IRON. *Terh. Chem. Ger. Eisen. Fr. Fer.* Known from the earliest times, for bars of iron were used to hold together masses of stone in the Egyptian Pyramids. Iron and steel (natural steel) were employed by the Greeks and Romans. The iron works of Styria commenced about the 8th Cent. The low furnaces at first used were made higher about the 12th Cent., and the present blast furnaces probably introduced in the 15th Cent. The leathern bellows were replaced about the end of the 16th Cent. by wooden ones, which were afterwards made of square boxes. Towards the close of the 17th Cent., blistered steel was first made. Coke was used about 1720 in the blast furnace, and the raw coal in 1784, for puddling iron. Within the present century the iron cylinder blast, huge furnaces, the use of the hot blast (1830), and of anthracite (1837), &c., have entirely renovated the production of iron, causing the production and consumption of tons instead of pounds of the metal.

METALLURGY OF IRON.

Iron is obtained exclusively from its oxides, in various states of combination, called *ores*; as oxides, simple or hydrated, carbonates, and silicates. The ores are thrown into the furnace with limestone or flux, and fuel; and when a sufficient quantity of metal has collected on the hearth, it is run off into moulds, as *cast-iron*. The cast metal is then partially oxidized and reduced to the state of wrought or *bar iron*, which again, by being heated in charcoal, is converted into *steel*.

1. *Ores.* a. *Magnetic.* Occurs almost always crystalline (see **MAGNETIC IRON**), and is usually associated either with silex or with talcose

rock, as its gangue. It often occurs of a friable character and easily extracted, or it appears as a very solid mass, more difficult to obtain in smaller pieces. In general it does not work as easily as other kinds of ore. The purest ore contains less than 72 pr. ct. of iron, and some of it of superior quality averages 50 to 55 pr. ct.

b. *Specular.* (See **SPECULAR IRON**.) The specular ore is more abundant than the magnetic. It is, in its purest state, sesquioxide of iron, containing $69\frac{1}{2}$ pr. ct. iron. It presents several varieties, the more perfectly crystalline specular ore (*Ger. Eisenglanz; Fr. Fer oligiste*); the micaceous ore (*Ger. Eisenglimmer*), in shining scales; the red hematite (*Ger. Rotheisenstein, Rother glaskopf, Blutstein*), usually fibrous, rather more earthy and less pure than the preceding, and frequently containing manganese; and the red earthy ore, mixed with clay (red ochre), carbonate of lime, and more or less with the brown hematites.

c. *Brown hematite.* (See this Art.) This is the most abundant ore of iron, and most extensively diffused. It is essentially a hydrated sesquioxide of iron, with definite quantities of water. In its purest form it contains from 56 to 62 pr. ct. iron. Its varieties are the fibrous, which is very pure; the compact, more or less mixed with clay, and constituting pipe-ore, massive and porous; the bog ore (often containing phosphoric acid, from $\frac{1}{2}$ to 6 pr. ct.); yellow ochre, mingled with clay.

d. *Sparry ore.* (See **SPARRY IRON**.) It is essentially carbonate of the protoxide of iron. The crystalline variety, or sparry ore, is less abundant, and usually contains manganese. The earthy variety, clay iron stone, is a very abundant ore, usually accompanying coal, and contains more or less alumina, lime, and magnesia. The purest form of sparry iron contains 47-37 pr. ct. iron, but its average yield is below 40 pr. ct., and yet it affords a large proportion of the iron employed in the arts, at least in England.

Foreign ingredients. Silicate of iron is always found accompanying the ores of iron. Oxide of manganese is rarely wanting, and is often present in inconvenient quantity. Phosphate of iron is by no means a rare ingredient, and may be said to be characteristic of bog-ore. Pyrites, or sulphuret of iron, is very frequent in all ores of iron, and is often an annoyance to the smelter.

The following table conveys a general idea of the different ores of iron, in per centages:—

	Magnetic.		Specular.		Hydrated.		Sparry.	
	1.	2.	3.	4.	5.	6.	7.	8.
Protoxide of iron.....	17.9	} 69.5	—	—	—	—	44.9	50.3
Peroxide of iron	81.8		66.0	73.8	51.2	72.0	—	—
Oxide of manganese.....	—	—	2.5	3.4	2.8	—	10.3	1.0
Magnesia.....	—	—	1.8	—	—	—	1.6	1.0
Lime.....	—	—	2.5	3.4	—	—	1.0	0.3
Alumina.....	—	—	2.0	2.4	2.0	—	} 4.2	14.5
Silica.....	—	—	16.8	12.8	34.0	18.1		
Carbonic acid	—	—	3.8	2.2	—	—	37.0	—
Water.....	—	—	2.8	—	10.0	9.2	—	1.5
Metallic iron.....	70.5	50.9	45.8	51.17	35.5	49.9	31.1	34.9

1. From Lake Champlain. 2. From S. Carolina, (*J. C. E.*) 3. Specular oxide from La Voulte, France; the lime and magnesia are carbonates. 4. Micaceous oxide from Cherbourg, France. 5. Dark brown, compact hematite from Potter Co., Pennsylvania. 6. Light brown, compact hematite from the Delaware, below Easton, (*J. C. E.*) 7. Sparry iron from Stahlberg in Siegen, where a celebrated steel is made. 8. Clay iron stone from the coal measures. The content of iron in each is placed at the bottom of the column.

2. *Preparation of ores.* In the reduction of such a cheap metal as iron, but little cost is allowed to their preparation. The softer ores are often thrown directly into the furnace. The harder, sulphurous and other ores, are generally subjected to a gentle roasting or calcination, the object of which is, 1. to throw off volatile matter, or crack them, to allow the reducing gases to penetrate more freely through the mass; 2. to roast off as much of the sulphur from the pyrites as possible. It is a mistake to suppose that the throwing off volatile matter, as carbonic acid or water, in the furnace itself, tends to diminish its heat, for the ore thrown in at the tunnel head descends too slowly to produce any injurious effect in this way. Calcination is performed in heaps in the open air, a little charcoal or coal being thrown upon the heap to keep up a slow combustion, or in calciners constructed for the purpose. A moderate heat only is required; and rather than apply too high a heat, it would be better not to roast at all; for, beyond a certain point, the earthy matters of the ore and the oxide of iron begin to cement together, entering upon incipient infusibility; in which case reduction follows with much greater difficulty.

Ores are mingled together for several purposes,—either to get a better admixture of the earthy ingredients, suitable for forming a slag, or to get the best working richness of metal, or to produce a different quality of iron. It is rarely the case, that an ore contains exactly the quantity of siliceous and alumina to flux freely with lime, most being very siliceous; but by adding a soft, or argillaceous, to a hard, or siliceous ore, fluxion is facilitated. It is a mistake to suppose that the richest ores of iron are the best. Long experience has shown that the best average content of metal should be 50 to 55 pr. ct., so that a sufficient quantity of slag may be produced. Another effect produced by mixing ores cannot as yet be readily explained. The quality of metal is altered, and almost always improved; so that it has become a settled principle with ironmasters, that the mixture will in all cases improve the metal. If an ore yielding a cold-short metal be mixed in some proportions with one yielding a hot-short iron, the resulting metal is intermediate in its properties. Doubtless this fact has its influence, that the greater number of bases forms the best slag, and removes a larger proportion of foreign matter from the metal.

3. *Flux.* Limestone is the usual flux for iron ores, its object being to unite with the siliceous and alumina, forming silicates of lime

and alumina, and thus excluding oxide of iron from such a combination. But where an ore is more or less destitute of siliceous, and contains lime and alumina, siliceous becomes the flux to be added. A majority of ores have a superfluity of siliceous, and are frequently wanting in alumina. To such, limestone and clay, or argillaceous limestone, or an argillaceous ore should be added. (See Principles of GLASS and FLUX.) A study of these principles is decidedly important for the reduction of iron, especially in the U. S. See Berthier's "Essais par la voie sèche," for a more extended view.

4. *Blast.* Although wooden cylinders with a well-fitting piston are occasionally employed to drive the requisite air or blast into the furnace, yet the double-acting iron cylinder is generally used. Water power, formerly used to drive the bellows, is now generally superseded by steam power, a single engine being used to work two or more furnaces, if necessary. The cold blast is also more generally replaced by the hot blast; the air being heated, after leaving the cylinders, by passing through iron tubes which are either heated by the waste heat of the furnace, over the mouth, or by a separate fire; even the latter arrangement being more economical than the use of the cold blast.

5. *Furnace.* Pl. VII. figs. 4, 5, and 6 represent a blast furnace. It consists of a truncated pyramidal mass of stone, from 30 to 50 ft. high, with a double-coned, hollow centre, in which the ore, flux, and fuel descend, and arches below for admitting the blast and for running off slag and metal. At *a* is the mouth from 2 to 4 ft. diameter; *b* the double lining of fire-brick, with a layer of rammed sand on the outside; *c, d* the boshes, the width of which, estimated at its widest part, is from 10 to 18 ft., and the angle formed by the sloping sides varies from 50° to 60°; *e* is the hearth or crucible part, where the reduction takes place, slightly sloping, 4 to 7 ft. deep, 3 to 5 ft. wide. The hearth is constructed of coarse and pure sandstone (any highly siliceous rock), with the hearthstone, *f*, reposing on sand, and this again on a solid foundation of stone. The two opposite arches are the twyer arches, through which the blast enters by the pipe *g, g, g*, and is thrown into the furnace through the nozzle *h*. The twyer lining consists of two concentric cones of iron, with a stream of water passing between them to protect them, while the blast enters through the inner cone. At *i* is the working or tympan arch; *k* the tympan-stone, secured by an iron plate on the outside, which is fastened into the opposite sides of the arch; *l* the dam-stone, also secured by an iron plate, and fitting the whole breadth of the hearth, except a few inches, through which the metal flows. While the furnace is in blast, the space on the side of the dam-stone is stopped by a good binding sand, and the space between the tympan and dam kept covered with heaped coals or sand.

6. *Reduction.* The fuel, ore, and flux are thrown into the mouth, *a*, and gradually descend towards the hearth in proportion as the charges below are thrown off as slag and metal. The fuel employed is either charcoal for

the best iron, or coke or anthracite. Raw bituminous coal and half-charred wood have been employed, but are not in general use. Carbonic acid is no doubt generated by the blast entering the twyers, but as it rises is soon converted into carbonic oxide, which is the immediate reducing agent; for if the fuel contained carburetted hydrogen, it must have been dissipated before it reaches that part of the furnace where reduction takes place. The gas entering into the pores of the ore reduces a portion of oxide of iron to the metallic state, while the flux seizing the earthy matters forms a slag, and sets free another portion of oxide to be reduced. The iron and slag drop down together to the bottom of the hearth, where they separate by their specific gravities, the metal below and the slag above. The fused slag flows in a constant and slow stream over the dam, on the opposite side from that where the metal is to flow. From the flowing and appearance of the slag, the state of the furnace may be imagined. When the melted metal is observed near the top of the dam the blast is stopped, an opening is driven in the sand-plug at the side of the dam, and the metal flows in a torrent through a gutter into moulds, where it solidifies into pigs. When it has so far run out that slag appears in quantity, the opening is again plugged up, and the blast readmitted. The yield of metal varies with the size of the furnace, the nature of the ore, the manner of its working; being from 30 to 120 tons of metal per week.

7. *Refining.* A finery furnace, or run out fire, is a low furnace, a few feet square, in which the pigs are melted by a blast, entering by one or more twyers on one side, and the metal run out over a broad surface, forming a layer two or three inches thick, on which a quantity of cinder collects, and water is thrown. By the high heat of the blast furnace in presence of carbonic oxide and metallic iron, portions of the earths, phosphoric acid, &c., are reduced, and together with sulphur from pyrites, enter into the metal. By the run-out fire a large quantity of these substances separate, together with iron, constituting the cinder. When the metal has just flown out, the odor of sulphurous acid is very perceptible; and when the water is thrown on, sulphuretted hydrogen is developed. Berthier also found phosphoric acid in this cinder. These advantages of a run-out fire, therefore, prior to making bar-iron, are clearly seen. The gray metal thrown into the finery fire is converted into a fine-grained, white iron.

8. *Forging.* Cast iron is converted into bar-iron by a forge-hearth, or in a puddling furnace. The former is used with charcoal as fuel, for the better qualities of metal, and the latter with bituminous coal. *a.* The forge-hearth resembles a blacksmith's forge, with a shallow receptacle for the fused metal, and a blast entering at the back part. The charcoal is heaped upon the hearth and finery metal thrown on, together with rich cinder and slag; when in fusion, the slag is removed (containing the earthy impurities of the metal), a rod thrust into the metal, to turn it up, and expose it to the action of the blast, whereby carbon

is burned off; and when the iron separates and is only soft, but no longer in a fused state, it is collected on the end of a bar, removed from the fire, and hammered into a bloom. A little limestone may be added in the hearth, if the iron contain phosphorus, to diminish its cold-short character. (?)

b. *Puddling* is performed in a reverberatory, heated with bituminous coal. Pl. VIII. figs. 7, 8, and 9 represent a puddling furnace, and fig. 10 the top of the chimney. "It is bound generally with iron, as represented in the side view, fig. 7, by means of horizontal and vertical bars, which are joined together and fixed by wedges, to prevent them from starting asunder. Very frequently, indeed, the reverberatory furnaces are armed with cast-iron plates over their whole surface. These are retained by upright bars of cast iron applied to the side walls, and by horizontal bars of iron placed across the arch or roof. The furnace itself is divided interiorly into three parts, the *fire-place*, the *hearth*, and the *flue*. The fire-place varies from $3\frac{1}{2}$ to $4\frac{1}{2}$ ft. long, by from 2 ft. 8 in. to 3 ft. 4 in. wide. The door-way by which the coke is charged, is 8 in. square, and is bevelled off towards the outside of the furnace. This opening consists entirely of cast iron, and has a quantity of coal gathered round it. The bars of the fire-grate are movable, to admit of more readily clearing them from ashes. Fig. 8 is a longitudinal section referring to the elevation, fig. 7, and fig. 9 is a ground plan. When the furnace is a single one, a square hole is left in the side of the fire-place, opposite to the door, through which the rakes are introduced, in order to be heated. *a* is the fire-door; *b* the grate; *c* the fire-bridge; *d, d* cast iron hearth-plates, resting upon cast iron beams, *e, e*, which are bolted upon both sides to the cast iron binding-plates of the furnace; *f* is the hearth, covered with cinders or sand; *g* is the main working door, which may be opened and shut by means of a lever, *g'*, and chain to move it up and down. In this large door there is a hole 5 inches square, through which the iron may be worked with paddles or rakes; it may also be closed air-tight. There is a second working-door, *h*, near the flue, for introducing the cast iron, so that it may soften slowly, till it be ready for drawing towards the bridge. *i* is the chimney, from 30 to 50 ft. high, which receives commonly the flues of two furnaces, each provided with a damper-plate or *register*. *k*, fig. 8, is the tap or floss-hole, for running off the slag or cinder. Fig. 10 shows the main damper for the top of the common chimney, which may be opened or shut to any degree by means of the lever and chain.

"The length of the hearth is usually 6 ft., and its breadth varies from one part to another. Its greatest breadth, which is opposite the door, is 4 ft. In the furnace whose horizontal plan is given above, the sole exhibits, in this part, a species of ear, which enters into the mouth of the door; at its origin towards the fire-place it is 2 ft. 10 in. wide; from the fire it is separated, moreover, by a low wall of bricks (the fire-bridge) 10 in. thick, and from 3 to 5 in. high. At the other extremity its breadth

is 2 ft. The curvature presented by the sides of the sole or hearth is not symmetrical; for sometimes it makes an advancement, as is observable in the plan. At the extremity of the sole farthest from the fire, there is a low rising in the bricks of $2\frac{1}{2}$ in., called the altar, for preventing the metal from running out at the *floss-hole*, when it begins to fuse. Beyond this shelf the sole terminates in an inclined plane, which leads to the floss or outlet of the slag from the furnace. This floss is a little below the level of the sole, and is hollowed out of the basement of the chimney. The slag is prevented from concreting here, by the flame being made to pass over it, in its way to the sunk entry of the chimney; and there is also a plate of cast iron near this opening, on which a moderate fire is kept up, to preserve the fluidity of the scoriae, and to burn the gases that escape from the furnace, as also to quicken the draught, and to keep the remote end of the furnace warm. On the top of this iron plate, at the bottom of the inclined plane, the cinder accumulates in a small cavity, whence it afterwards flows away; whenever it tends to congeal, the workman must clear it out with his rake.

"The door is a cast iron frame, filled up inside with fire-bricks; through a small hole in its bottom the workmen can observe the state of the furnace. This hole is at other times shut with a stopper. The chimney has an area of from 14 to 16 inches. The hearth stands 3 ft. above the ground; its arched roof, only one brick thick, is raised 2 ft. above the fire-bridge and above the level of the sole, taken at the middle of the furnace. At its extreme point near the chimney, its elevation is only 8 inches; and the same height is given to the opening of the chimney.

"In most iron-works the sole is covered with a layer of refractory sand, from $2\frac{1}{2}$ to 3 inches thick, which is lightly beat down with a shovel. At each operation a portion of the sand is carried away, and is replaced before another. Within these few years, there has been substituted for the sand a body of pounded slags; a substitution which has occasioned, it is said, a great economy of iron and fuel.

"The fine metal obtained by the coke is *puddled* by a continuous operation, which calls for much care and skill on the part of the workmen. To charge the puddling furnace, pieces of *fine metal* are successively introduced with a shovel, and laid one over another on the sides of the hearth, in the form of piles rising to the roof; the middle being left open for puddling the metal, as it is successively fused. Indeed, the whole are kept as far separate as possible, to give free circulation to the air round the piles. The working-door of the furnace is now closed, fuel is laid on the grate, and the mouth of the fireplace, as well as the side opening of the grate are both filled up with coal, at the same time that the damper is entirely opened. The fine metal, in about twenty minutes, comes to a white-red heat, and its thin-edge fragments begin to melt and fall in drops on the sole of the furnace. At this period the workman opens the small hole

of the furnace door, detaches with a rake the pieces of fine metal that begin to melt, tries to expose new surfaces to the action of the heat, and in order to prevent the metal from running together as it softens, he removes it from the vicinity of the fire-bridge. When the whole of the fine metal has thus got reduced to a pasty condition, he must lower the temperature of the furnace, to prevent it from becoming more fluid. He closes the damper, takes out a portion of the fire and the ribs of the grate, and also throws a little water sometimes on the semi-fused mass; he then works about with his paddle the clotty metal, which swells up with the discharge of gaseous oxide of carbon, burning with a blue flame, as if the bath were on fire. The metal becomes finer by degrees, and less fusible; or, in the language of the workmen, it begins to get *dry*. The disengagement of the oxide of carbon diminishes, and soon stops. The workmen continue, meanwhile, to puddle the metal, till the whole charge be reduced to the state of incoherent sand; and at that time the ribs of the grate are replaced, the fire is restored, and the register is progressively opened up. With the return of the heat, the particles of metal begin to agglutinate, the charge becomes more difficult to raise, or, in the labourers' language, it *works heavy*. The refining is now finished, and nothing remains but to gather the iron into balls. The founder with his paddle takes now a little lump of metal as a nucleus, and makes it roll about on the surface of the furnace, so as to collect more metal, and form a ball of about 60 or 70 pounds weight. With a kind of rake, called in England a *dolly*, and which he heats beforehand, the workman sets this ball on that side of the furnace most exposed to the action of the heat, in order to unite its different particles, which he then squeezes together, to force out the scoriae. When all the balls are fashioned (they take about 20 minutes work), the small opening of the working-door is closed with a brick, to cause the heat to rise, and to facilitate the welding. Each ball is then lifted out, either with tongs, if roughing rollers are to be used, as in Wales, or with an iron rod welded to the lump as a handle, if the hammer is to be employed, as in Staffordshire.

"The charge for each operation is from $3\frac{1}{2}$ to 4 cwt.; and sometimes the cuttings of bar-ends are introduced, which are puddled apart. In good working, the loss is from 8 to 10 pr. ct. In Wales, the consumption of coal is estimated at one ton for every ton of fine metal. About five puddling furnaces are required for the service of one smelting furnace and one finery." *Ure's Dic.* 701—703.

The theory of reducing cast to bar-iron is, that the carbon is more or less burned off by the air admitted. As a large quantity of iron is lost by oxidation at the same time, the rich slags may be used in the blast furnace, or, to make an inferior iron, in a forge fire; but if the metal contained phosphorus, it is perhaps better to submit to the loss of iron. While the carbon is oxidizing, silicon, aluminum, phosphorus, sulphur, iron, &c., are oxidized at

the same time, and pass off in the cinder, so that the operation of puddling is at the same time a purifying or refining process. Improvements of this process will doubtless be introduced, by which a greater purity of metal will be attained, attended with less loss of iron.

9. *Steel*. Wrought, or bar-iron is converted into steel by imbedding the bars in layers of charcoal dust, in a long crucible furnace, in which are many alternate layers of bars and charcoal, and the whole is covered with sand, to exclude the air. The fire built below plays around the whole crucible, which is maintained at a high heat for several days (4 to 10), according to its size, &c. When the bars are taken out, they are covered with blisters (whence blistered steel), and are somewhat brittle, while their fracture shows a white and crystalline metal, totally different from the bar-iron introduced into the furnace. The carbon in which the bars were imbedded gradually progresses from the exterior to the centre, as shown by analysis at different depths in a bar, and by the streak of wrought iron in the centre when they are not perfectly converted.

Cast-steel. As the steel in the blistered bars is not very uniform in character, it may be rendered so by fusion. The bars are broken up, put in small crucibles, well covered, and heated by a wind furnace until fusion has taken place, when the crucible is removed, and its contents poured into moulds.

Shear steel is made by breaking the blistered bars into pieces of some 18 inches length, 4 of which are bound together by a thin steel rod, heated, tilted, again heated, and drawn out to the dimensions of a single bar.

VARIOUS PROCESSES.

1. *Catalan-forges*. In which bar-iron may be made directly from the ore, without passing through the intermediate state of cast-iron. The furnaces are very low, resembling a simple forge-hearth, and in fact a blacksmith's hearth may be used for the purpose. The blast is usually produced by a stream of water descending a vertical pipe, from lateral openings in which it catches air, and discharges it in a basin, from which the water passes out below, and the air through an opening above. Only rich ores can be worked by this method, for a large proportion of the oxide of iron itself is the flux for slagging the siliceous ore, and hence they rarely obtain more than 33 pr. ct. metal. A little lime is sometimes used, to prevent loss of iron; but if the ore contains manganese, the greater part of it passes into the slag with little iron, and the metal produced is like natural steel. When the slags

have formed, they are run off, and the metal, disseminated in grains, is worked together into a *loup* (wolf), which is bloomed under the hammer. Similar forges are worked in Delaware, New Jersey, &c. Another process consists in making cast-iron in a low furnace, and then working it into bar-iron on the hearth of the same furnace.

2. *Cemented bar-iron*. In this process which has been latterly attempted, but, I believe, not yet perfected, a pure ore, in powder, is imbedded in charcoal powder, and heated for several days, in a closed crucible.

3. *Natural steel*. This is probably the most ancient process, and consisted in making cast-iron in a low furnace, and partly burning of the carbon on the hearth of the same; it is now, however, practised on cast-iron made in an ordinary blast furnace. White iron is used, and mostly such as contains manganese. This is thrown by a blast on a shallow hearth, and when fused the blast is slackened, and little hammer-slack or fine ore thrown on and stirred in, which renders the mass pasty. Another piece of casting added renders it fluid again; when this has become stiffer, another piece is added with slack, which causes ebullition upon stirring. A 4th and 5th piece is added, and the whole well stirred. When all has been added, the mass is taken out of the fire, and divided into several pieces. The mass is very unequally steeled in different parts, and in order to render it more homogeneous, it is made into strips, which are laid together, soft and hard alternating, welded, and rolled into a bar. To produce still better qualities, the same operation is repeated, constituting steel, *twice, thrice marked*, &c.

COMPOSITION OF IRON AND STEEL.

Cast iron. There are two well-marked varieties of cast-iron, the *gray* and the *white*. Both are essentially composed of carbon and iron, together with small quantities of silicon, manganese, phosphorus, &c., as accidental impurities. The white contains all the carbon combined with the iron; the gray may contain the same amount of carbon, but a portion of it has been precipitated by slower cooling, in the form of black scales of graphite, which contrast with the whiter iron, and give a gray color. Sometimes this separation of graphite takes place in spots, and produces what is termed *mottled iron*. When the graphite separates in quantity and in large laminæ, the result is *black iron*. A variety of brilliant, white iron is also produced in the blast furnace, from ores containing manganese. The following analysis may serve to show the composition of cast-iron:—

Gray Cast-iron.

	With Charcoal.							With Coke.				
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Iron.....	95.97	95.67	96.4	96.2	91.1	91.4	95.0	92.1	92.2	94.2	95.3	95.57
Manganese.....	—	—	—	—	—	2.8	0.9	1.8	—	—	—	—
Carbon.....	2.10	2.26	2.4	3.5	2.6	1.9	3.0	3.0	4.3	2.3	2.2	2.32
Silicon.....	1.06	1.03	1.2	0.3	0.4	0.2	—	4.5	3.5	3.5	2.5	1.92
Phosphorus....	0.87	1.04	—	—	3.1	5.6	—	0.2	—	—	—	0.19

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1—7 were made with charcoal, 8—11 with coke, and 12 with both coke and charcoal; hence coke-made iron contains more silicon. 1 from Champagne; 2, Nivernais; 3, Ancy-le-Franc; 4, Autrey; 5, Torgelow, in Pomerania; 6, Pertz (the two last from bog-ore); 7, Alevard, from sparry iron (it makes a good natural steel, and contains 0·2 of copper); 8, Firmy; it inclines to mottled iron, and contains 0·2 sulphur; 9, Janon, near St. Etienne,

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inferior quality; 10, Charleroi, Belgium, said by Berthier to make the best castings on the Continent; it is very dark gray, and is derived from a more modern calcareous formation; 11, an English dark gray, almost black, excellent for castings; although both 10 and 11 are excellent for castings, they contain less carbon than usual, and although coke is used, they enclose less silicon; 12, Berry, gray iron made by coke and charcoal mixed.

White Cast-iron.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Iron	91·16	96·0	95·2	96·13	94·68	94·33	95·65	—	90·8	89·8	86·9	
Manganese	4·57	—	—	—	2·14	2·59	2·49	6·3	5·2	4·5	7·4	
Carbon	3·90	3·6	3·6	2·33	2·64	2·69	2·44	—	3·5	5·1	4·4	1·7
Silicon	0·25	0·4	0·5	0·84	0·26	0·23	0·23	0·5	0·5	0·6	1·3	0·5
Phosphorus.....	—	—	0·7	0·70	0·28	0·16	0·19	—	—	—	—	

1, Leke, Sweden (it also contains 0·12 magnesium); 2, St. Dizier, with large laminæ; 3, Trédion, very brittle; 4, Champagne; 5, Isère, 6, Siegen; 7, Coblenz; 8, Bendorf, on the Rhine; 9, Lobe in Siegen (Rhine); 10 and 11 from Ham (Lamark); 10 is lamellar and white, 11 is gray, although containing more manganese; 12, Firmy, the same as No. 8 of gray metal, but refused in a finery fire, which evidently burns off a portion of carbon and

silicon. Nos. 6—11 are obtained from sparry ores. 1 was analyzed by Berzelius, 4—7 by Gay-Lussac and Wilson, the rest by Berthier. The brittleness of white iron does not depend on the quantity of carbon, for the fine metal, 12, can be pulverized in a mortar.

The following analyses of the amount of combined and free carbon (graphite), seem to prove that the gray has more of the latter, while the total amount of carbon is the same:—

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Combined carbon	0·89	1·03	0·75	0·58	0·95	0·93	1·51	2·52	2·91	3·10
Free “	3·71	3·62	3·15	2·57	2·70	2·34	1·04	0·50	0·55	0·72
Total, carbon	4·60	4·65	3·90	3·15	3·65	3·27	2·55	3·02	3·46	3·82

1—6 are gray irons; 2, 3 are from sparry ores; 4, 5, by coke, from an ochrey ore. 7—10, white iron, from Bernburg; 10 is a brilliant white, with 7 pr. ct. manganese.

The following analyses are of cast-iron, made by cold and hot blast:—

	1.	2.	3.	4.
Iron	93·29	91·42	93·66	91·98
Combined carbon	2·78	1·44	0·48	0·95
Free carbon.....	1·99	2·71	3·85	3·48
Silicon.....	0·71	3·21	0·79	1·91
Phosphorus	1·23	1·22	1·22	1·68
Spec. grav.....	7·166	7·166	7·081	7·077

1, mottled iron, from Königshütte, on the Harz, with cold blast. 2, the same, with the blast at 470°. 3, gray iron, from Leerbach, on the Harz, with cold blast; and 4 the same, with blast heated to 230°. *Eodemann.*

Silicon and manganese disappear readily by finery or forge-fires, and seem to exert no important influence on the metal, unless contained in it in large quantity. Phosphorus (and probably arsenic) makes iron cold-short, flow more freely and congeal more slowly, and hence adapts it to fine mouldings; but with 1·5 pr. ct. it becomes rather brittle. Sulphur makes the metal thick-flowing, and adapts it less to fine castings; it produces a hot-short metal, and with 0·37 pr. ct. it makes a useless bar-iron. Smaller quantities can be readily worked off by run-out fires.

Malleable castings are made by heating

them imbedded in chalk, ashes, charcoal, oxide of iron, in which it would appear that little more than a molecular change is produced. By rapid cooling white iron is produced from gray, and by slow cooling, gray from white. In the blast-furnace gray results when the furnace is working to the greatest advantage; with too large a proportion of fuel it becomes almost black, and with too much ore in proportion to fuel it becomes white.

By heating cast-iron in the air to redness it loses its carbon, and becomes oxidized the deeper, the longer the heat is continued; but if not continued too long, the interior has become soft and malleable. A similar change takes place, by long exposure to the air, of cast iron which has been frequently heated (as in broken gas-retorts), when the iron becomes nearly as soft as bar-iron. By the action of somewhat dilute nitric acid in the cold, metallic iron is dissolved, and there remains a brown mould, soluble in alkali and precipitable by acid, and distilling with the odor of an empyreumatic oil and ammonia. By solution in dilute sulphuric acid, hydrogen is evolved of a disagreeable odor, containing a volatile oil together with sulphuretted and phosphuretted hydrogen. When a large quantity of a sulphuretted hydrogen solution, made from artificial sulphuret of iron, has become stale by standing, there is evolved an odor that resembles oil of mustard, and attacks the eyes most painfully; probably due to the formation of a sulphuretted oil, from the carbon in the iron, with the hydrogen and sulphur.

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(*J. C. Booth.*) Cannon-balls left under seawater for 42 years, were partly corroded, leaving a coating of greater or less thickness, of a substance resembling graphite, probably composed of FeC_3 . Some of the graphite

IRON.

precipitated in gray metal is almost pure carbon, and the iron can be extracted from it by dilute acid, just as from mineral graphite.

Bar-iron. The following analyses show the composition of bar-iron:—

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Combined carbon.....	0.293	0.240	0.193	0.144	0.238	0.38	0.104	0.237	0.66
Free ".....									
Silicon.....	—	0.025	0.015	0.070	—	—	0.220	0.260	—
Phosphorus.....	0.077	—	0.210	0.510	—	—	—	—	—

1 and 2 are best bar-iron, from Sweden; 3 from Champagne, (see 1, gray cast); 4, cold-short, from the Mosel, (*Gay-Lussac* and *Wilson*); 5—10 from Bernburg, analyzed by *Bromeis*, (see 6—10, carbon in cast iron).

Steel. The following analyses show the composition of steel:—

		Carbon.	Silicon.
Blistered, softest,	<i>K.</i>	0.9	—
" harder,	<i>K.</i>	1.3	—
" " "	<i>K.</i>	1.7	—
" English,	<i>Be.</i>	1.87	0.1
" Elberfeld,	<i>Br.</i>	0.496	—
Cast,	<i>Be.</i>	1.65	0.1
" Engl. soft,	<i>M.</i>	0.83	—
" " common,	<i>M.</i>	1.00	—
" " harder,	<i>M.</i>	1.11	—
" " hardest,	<i>M.</i>	1.67	—
" " best,	<i>Er.</i>	1.17	—
" Rhenish,	<i>Br.</i>	1.267	—
" " "	<i>K.</i>	2.8—3.00	—
" " "	<i>B. E.</i>	1.758	—
" remelted,	<i>B. E.</i>	1.578	—
" Engl. best,	<i>G. W.</i>	0.625	0.03
" French,	<i>G. W.</i>	0.936	0.08
Wootz,	<i>Fe.</i>	1.50	0.60
" "	<i>Far.</i>	—	0.316

K. analyzed by *Karsten*; *Fe.* by *Berthier*; *Br.* by *Bromeis*; *M.* by *Mushet*; *B. E.* by *Böttger* and *Elsner*; *G. W.* by *Gay-Lussac* and *Wilson*; *Far.* by *Faraday*.

Wootz contains also aluminum, about twice as much as of silicon, and according to *Faraday* and *Stoddart* it may be imitated by fusing the compound Fe_4C with alumina, and then fusing 1 pt. of this alloy with from 8 to 17 pts. blistered steel.

Steel will oxidize less easily than bar-iron, and more easily than cast-iron. It may be heated to low ignition in the air with losing its properties, but by repeated ignition, a little carbon being burned off each time, it finally becomes bar-iron. Nitric acid makes a black spot on steel, by dissolving iron and leaving graphite, which is changed by long-continued action of the acid into a brown mould. Dilute sulphuric or muriatic acid dissolves steel, evolving hydrogen of a disagreeable odor (from a hydrocarbon oil), and leaving graphite. The acids act on steel less violently than on bar-iron, and leave more graphitoid, (FeC_3). If fused with minute quantities of other metals, the solution is much more rapid; thus, platinum-steel evolves 100 times as much hydrogen in a given time as pure steel.

Steel holds a medium position between bar and cast-iron, in composition and in most of

its properties; but it seems to have all the valuable properties of each. It has a rather whiter color than iron.

PROPERTIES OF IRON AND STEEL.

Bar-iron exhibits a tendency to crystallize in octahedra, with cubical cleavage, but it usually exhibits a fibrous structure, due to working it. It is the hardest and toughest of ductile metals; it is the most tenacious of all metals, and can be drawn out to very fine wire, but cannot be rolled into thin sheets; its spec. grav. = 7.79, when almost pure; it is attracted by the magnet, but loses its magnetism almost immediately after contact, if pure. It fuses at about 2850° , but far below this point it burns in the air, forming oxide—sesquioxide; its combustion in oxygen is much more vivid. In dry air it remains unchanged, but in moist air oxidizes, especially if its surface be smooth and polished. Under water it rusts (oxidizes), but not in alkaline solutions of potassa, soda, ammonia, lime, &c. The purer the iron, the more easily does it rust. Contact of zinc protects it as long as the zinc is bright; tin hastens its oxidation. It is sometimes coated externally with zinc, and then termed galvanized iron. The presence of free acid hastens the oxidation of iron. Heated to whiteness it decomposes water, evolving hydrogen, and becoming magnetic oxide. When acted upon by cold, dilute nitric acid, it sometimes occurs that no hydrogen is evolved, but the latter unites with nitrogen and forms ammonia ($8\text{Fe} + 10\text{NO}_5 + 3\text{HO} = 8(\text{FeO}, \text{NO}_5) + \text{NH}_3, \text{NO}_5$). In strong fuming, nitric acid, or in nitro-sulphuric, especially by contact with platinum, it is rendered *passive*.

Steel. It is more easily oxidized by heat and acids than cast-iron, and less easily than bar-iron. Nitric acid, dilute, produces a black spot on its surface, from the separation of carbonaceous matter, which becomes mould, soluble in alkali, by the farther action of the acid. Hardened steel is less easily acted upon by acid than soft steel. Soft blistered steel dissolves slowly in dilute nitric acid, forming mould without graphite; cast-steel dissolves still more slowly. Nitric acid acting only on the surface, develops the internal structure of steel, showing whether different kinds have been welded together; this action characterizes wootz, which shows an interweaving of different kinds, more or less silvery, some containing more carbon or aluminum, and being more crystalline. Dilute sulphuric and muriatic acids act on steel with the evolution of a disagreeably-smelling hydrogen; the harder the steel, the less intense the action.

IRON.

COMPOSITION OF SLAGS AND SCORIÆ.

Blast-furnace slags. The following analyses, by Berthier, exhibit not only the composition

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
Silica	44.4	50.2	55.2	39.0	60.0	63.6	62.8	59.8	31.1	53.0	71.0	47.0	40.4
Lime	28.4	35.4	19.2	19.6	20.6	24.0	19.4	19.9	14.1	15.0	7.2	20.6	27.2
Magnesia	1.6	0.6	1.4	2.4	7.2	1.2	1.2	11.9	34.2	8.0	5.2	—	1.2
Protox. iron	4.4	0.8	3.4	5.0	3.0	1.7	6.2	2.0	1.0	10.0	5.0	4.6	21.0
“ manganese	2.0	—	1.4	—	3.6	3.9	—	—	4.4	10.0	6.5	3.0	0.8
Alumina	17.0	12.6	19.2	26.0	7.4	3.8	8.4	5.7	8.9	1.0	2.5	23.9	16.8
Titanic oxide	—	—	—	—	—	—	—	—	9.0	—	—	—	—
	97.8	99.6	99.8	98.0	101.8	98.2	98.0	99.3	102.7	97.0	97.4	99.1	97.4

	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.
Silica	52.8	57.0	45.4	49.6	48.4	37.8	40.6	43.2	35.4	36.6	38.8	46.6	33.5
Lime	5.6	5.6	4.2	—	—	—	32.2	35.2	33.4	35.8	37.0	28.3	43.0
Magnesia	9.0	13.8	8.6	15.2	10.2	8.6	—	4.0	1.2	4.8	3.2	—	1.0
Protox. iron	1.4	6.8	1.8	0.4	0.1	21.5	10.4	4.2	1.2	2.0	4.4	1.8	1.0
“ manganese	26.2	5.4	33.4	25.8	34.0	29.2	—	—	2.6	—	—	2.6	1.0
Alumina	3.4	10.6	4.6	9.0	6.6	2.1	16.8	12.0	16.2	18.4	15.2	18.8	19.0
Sulphur	—	—	0.7	0.1	0.1	—	—	—	1.4	1.0	0.8	1.2	1.0
	98.4	99.2	98.7	100.1	99.4	99.2	100.0	98.6	96.7	98.6	99.4	99.3	99.5

Nos. 1 to 19 were from furnaces using charcoal; 20 to 26, coke. Nos. 1 to 9 were from ores of peroxide; 10 to 19 from sparry ores; the rest from coal ores. No. 1. France; from a granular ore; slag compact, vitreous, greenish gray, very fusible. 2. Ancy-le-Franc; like the preceding; very fusible, although containing much lime. 3. France; gray and stony; the furnace working badly, and slag not fusible enough, from too little lime. 4. France; granular ore; slag sufficiently fusible, but sluggish; more silex required. 5. France; Requires more flux. 6. from Torgelow, in Pomerania, from bog-ores, containing much phosphate; slag a bluish white enamel. 7. France; is greenish blue, the furnace working well, and producing gray metal. 8. Gesberg, Sweden; magnetic ore; slag vitreous, transparent, very fusible. 9. Taberg, Sweden; magnetic ore; slag porous, yellow on the surface, iron-gray in the interior, little fusible; contains 9 pr. ct. titanic oxide. The following are from sparry ores:—10 and 11. Savoy; 10 is black, porous, and very light; runs when the furnace begins to work badly; 11 grayish yellow, porous, scarcely fused, full of quartz, coal, and iron; the furnace working very badly. 12. France; partly glassy, partly stony, greenish gray; very fusible; containing much sulphuret of calcium. 13. Normandy; furnace working badly; slag both glassy and stony, crystalline, puffed. 14, 15, 16. Musen, Siegen on Rhine; sparry ores of Stahlberg; 14 glassy and stony, very fusible; furnace producing lamellar white metal; 15 glassy and stony, blebby, bottle-green; furnace yielding mottled iron; 16 a blebby, sulphurous slag, olive-green. 17, 18, 19. Hamm, Lamarch; mixed sparry ore and brown hematite, without flux; 17, when the metal is gray; 18, metal white, lamellar; 19, metal white, cavernous, furnace overcharged with ore.

of slags, but also the differences resulting from the employment of different ores, different fuel, and when the furnace is working differently.—

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The following are from coal ores chiefly, and worked with coke:—20. Dudley, Birmingham; furnace working well; slag compact, greenish gray. 21, 22. Dowlais, Merthyr Tydvil, Wales; stony, bottle-green, cavities coated with idocrase; 22, black, opaque, furnace working badly. 23, 24. St. Etienne, France; 23, vitreous, semi-transparent, very hard, bluish gray; furnace yielding gray metal; 24, grayish brown; furnace yielding white metal. 25, 26. France; 25 translucent, vitreous; 26 stony, opaque; obtained by adding more flux, whereby the quality of the metal was improved.

A study of the above will exhibit many facts of interest:—That protoxide of iron or manganese may replace lime in a slag, is shown by comparing 14 to 18, with all the rest. That a large amount of magnesia may enter into a slag without injury to its fusibility. That a small amount of alumina will be replaced by a larger amount of oxides of manganese and iron. A furnace in general works best, when the slags contain

40 to 55 pr. ct. silica.

20 “ 35 “ “ lime.

10 “ 20 “ “ alumina.

The lime includes magnesia and protoxides of manganese and iron. When a furnace is running white metal, the slag usually contains a little iron, unless the ore be manganese. By increasing the quantity of lime, sulphur, and perhaps phosphorus tend to pass into the slag.

Percy and Forbes have made a minute examination of some crystalline slags, which show a greater admixture of foreign substances than the above. Some of their results follow. Nos. 1, 2, 3, 4, 6, 7, and 10, from hot blast furnaces; 5, from cold blast. 1, 2, 3, 4, from near Dudley; 5, Tipton; 7, Oldbury, Engl.; 6 and 10, Belgium; 8 and 9, Olsberger furnaces, on the Rhine. *Chem. Gaz.* v. 293.

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	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Silica.....	38.05	38.76	37.63	37.91	39.52	42.06	28.32	53.37	53.76	55.77	45.59
Alumina.....	14.11	14.48	12.78	13.01	15.11	12.93	24.24	5.12	4.76	13.90	11.88
Lime.....	35.70	35.68	33.46	31.43	32.52	32.53	40.12	30.71	29.48	22.22	38.20
Magnesia.....	7.61	6.84	6.64	7.24	3.49	1.06	2.79	9.50	9.82	2.10	—
Protoxide manganese	0.40	0.23	2.64	2.79	2.89	2.26	0.07	1.41	1.30	2.52	0.91
“ iron.....	1.27	1.18	3.91	0.93	2.02	4.94	0.27	0.95	1.48	2.12	1.11
Potassa.....	1.85	1.11	1.92	2.60	1.06	2.69	0.64	—	—	1.78	—
Sulphuret of calcium	0.82	0.98	0.68	3.65	2.15	1.03	3.38	—	—	—	1.76
	99.81	99.26	99.66	99.56	98.76	99.50	99.83	101.06	100.60	100.41	99.45
Hardness.....	6.0	6.0	6.0	5.5	5.7	—	5.7	5.0	5.7	—	—
Spec. grav.....	2.905	2.915	2.924	2.919	—	(0.31	0.26)	—	—	—	—

In No. 6 the 0.31 is phosphate of alumina; in 7 the 0.26 is sulphate of lime. Slags from No. 1 to 6 are composed according to the formula $2(3\text{RO}, \text{SiO}_3) + \text{Al}_2\text{O}_3, \text{SiO}_3$, in which $\text{RO} = \text{CaO}, \text{MgO}, \text{FeO}, \text{MnO}$; it is probably either Vesuvian, with 1 equiv. of $3\text{RO}, \text{SiO}_3$ in excess, or it is Gehlenite, with a deficiency of alumina; it agrees exactly with both in crystalline form, and with massive gehlenite

in composition. No. 7 has the formula $3(3\text{CaO}, \text{SiO}_3) + 3\text{Al}_2\text{O}_3, \text{SiO}_3$, which, according to Percy, more closely agrees with the analyses of gehlenite than the formula usually given, which has only $2\text{Al}_2\text{O}_3$. 8 and 9 approach augite in composition. 11 approaches the formula of humboldtite.

Scoriae. The following are from Berthier:—

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Silica.....	22.5	31.1	23.0	19.0	8.0	19.0	7.6	17.2	27.6	36.8	42.4	22.76
Protox. iron.....	71.0	31.4	45.0	51.5	80.0	64.8	82.1	61.3	61.2	61.0	52.0	61.28
Protox. manganese	2.0	27.4	29.0	10.5	3.5	12.6	6.8	0.5	—	0.9	—	3.58
Lime.....	2.0	3.2	2.0	17.0	7.0	1.8	—	2.7	—	—	—	3.41
Magnesia.....	—	2.4	1.0	1.0	0.5	0.4	2.8	0.1	—	—	—	0.76
Alumina.....	2.5	3.6	1.0	1.0	0.5	—	1.1	0.2	4.0	—	3.3	7.30
	100.0	99.1	101.0	100.0	99.5	98.6	100.4	82.0	92.8	98.7	97.7	99.09

1 and 2 are scoriae from Catalan forges. 3—6 are from refineries of manganesian ore; 3—5, from Allevard, France; 6, from Musen, Rhine. 7, 8, from refining common cast-iron; 8, from the cold-short, phosphoric iron of Torgelow, in Pomerania, containing, in addition to the above, 16.5 pr. ct. phosphoric acid. 9, refinery with coal, Dudley, Engl.; has in addition 7.2 pr. ct. phosphoric acid. 10, puddling furnace of Dowlais, Wales; has 1.7 phosphoric acid in addition. 11, from reheating furnace, Dowlais. 12, refinery cinder, (Percy); it has 0.46 sulphur in addition.

Of the two following, given by Percy, 1 was from the flue of a puddling furnace, and 2 from tap-cinder.

	1.	2.
Silica.....	29.60	23.86
Protox. iron.....	48.43	39.83
Perox. “.....	17.11	23.75
Protox. manganese.....	1.13	6.17
Alumina.....	1.28	0.91
Lime.....	0.47	0.28
Magnesia.....	0.35	0.24
Phosphoric acid.....	1.34	6.42
Sulphuret iron.....	1.61	0.62
	101.32	102.08

The number of various oxides in these cinders shows how refining operations, &c., tend to oxide the foreign matters in cast-iron, together with a portion of iron. It will be observed that phosphorus is carried off in large quantity; hence it would not be proper to throw such scoriae into the furnace, as it would increase the cold-short character of the

metal. That sulphur is thrown off largely in the run-out fires, I have often observed, from the odor of sulphurous acid, when the metal is first run off, and that of sulphuretted hydrogen, when water is sprinkled over the hot mass. J. C. B.

PRODUCTS OF COMBUSTION IN THE BLAST FURNACE.

The labors of Bunsen and others have enabled us to form a correct view of what is taking place within the furnace; and the masterly investigations of Bunsen and Playfair, contained in the Rep. of the British Association for 1845, leave little to be desired on this head, excepting a similar series of experiments with anthracite. The following results of Bunsen, in 1841, were obtained from smelting Mansfield copper-slate. The gases are N, nitrogen, Co_2 carbonic acid, Co carbonic oxide, CH carburetted hydrogen, H hydrogen, So_2 sulphurous acid; the last partly from the ore and partly from the coke.

	1.	2.	3.	4.
N.....	68.45	68.31	66.94	67.97
Co_2	11.81	10.62	10.67	7.41
Co.....	13.62	17.19	18.03	19.07
CH.....	2.63	2.81	3.49	3.77
H.....	1.94	0.00	0.00	0.02
So_2	1.55	1.07	0.87	0.86

	1.	2.	3.	4.
N.....	70.52	68.99	66.74	64.66
Co_2	21.03	23.42	18.30	20.11
Co.....	2.79	0.61	5.52	11.05
CH.....	1.47	5.86	2.07	0.53
H.....	3.17	0.00	6.89	3.44
So_2	1.04	1.12	0.48	0.21

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The upper division contains the gases collected from the upper part, and the lower from the lower part of the furnace. No. 1 was from coke with hot blast; No. 2, coke and $\frac{1}{2}$ charcoal, with hot blast; 3, charcoal with hot blast; 4, charcoal with cold blast. He calculated that the amount of heat realized and lost was

	Realized.	Lost.
From 1	60.8	39.2 pr. ct.
" 2	58.8	41.2 " "
" 3	56.2	43.8 " "
" 4	50.4	49.6 " "

Height above twyer.....	17 $\frac{3}{4}$ ft.	16 $\frac{1}{4}$.	14 $\frac{3}{4}$.	13 $\frac{1}{4}$.	11 $\frac{1}{4}$.	8 $\frac{1}{4}$.	5 $\frac{3}{4}$.
Nitrogen.....	62.34	62.25	66.29	62.47	63.89	61.45	64.58
Carbonic acid.....	8.77	11.14	3.32	3.44	3.60	7.57	5.97
" oxide.....	24.20	22.24	25.77	30.08	29.27	26.99	26.51
Light carb. hydrogen.....	3.36	3.10	4.04	2.24	1.07	3.84	1.88
Hydrogen.....	1.33	1.27	0.58	1.77	2.17	0.15	0.16

Height above twyer.....	23 ft.	20 $\frac{1}{2}$.	18.	15 $\frac{1}{2}$.	13.	10.
Nitrogen	64.43	62.65	63.20	64.28	66.12	64.97
Carbonic acid.....	22.20	18.21	12.45	4.27	8.50	5.69
" oxide	8.04	15.33	18.57	29.17	20.28	26.38
Light carb. hydrogen.....	3.87	1.28	1.27	1.23	1.18	0.00
Hydrogen.....	1.46	2.53	4.51	1.05	3.92	2.96

The gas at 8 $\frac{3}{4}$ ft. height was anomalous in composition. In both cases the carbonic acid diminishes in descending, and again somewhat increases lower down; the carbonic oxide attains a maximum about the middle of the furnace, and diminishes in a greater ratio upward than downward; the carburetted hydrogen remains constant in the upper part, and diminishes in the lower part. The results of Ebelen, in France, are shown by Bunsen and Playfair to be erroneous, as he gives no carburetted hydrogen, while they prove that well-made charcoal from beech, fir, and oak, still give off a large proportion of carburetted hydrogen.

Since a dry distillation of the fuel takes place in the furnace, B. and P. determined, separately, the products of such a distillation of the fuel (bituminous coal), used at the Alfreton iron works. The following table contains these results by weight:

	1.	2.	3.
Carbon	68.925	67.228	65.123
Tar	12.230	9.697	16.594
Water	7.569	12.397	
Light carb. hydrogen .	7.021	6.638	6.233
Carbonic oxide	1.135	1.602	6.328
" acid.....	1.073	1.139	2.289
Cond'nsd hydrocarbon	0.753	0.513	1.559
Sulphuretted hydrogen	0.549	0.253	0.172
Hydrogen	0.499	0.370	1.421
Ammonia.....	0.211	0.163	0.281
Nitrogen.....	0.035	—	—
	100.000	100.000	100.000

The condensed hydrocarbon, in 1, includes olefant gas, and in the 3 it is wholly this gas.

No. 1 was obtained by beginning to heat the closed end of the tube in which the distillation took place, so that the liquids would first condense in another part of the tube, and be vola-

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Hence one-half of the heat is lost with the cold blast.

The following tables contain the results of Bunsen's experiments on the iron blast furnace at Veckerhagen, in Hessia (Electoral), and of Scheerer and Langberg at Baerum, near Christiania, Norway, in both of which charcoal was the fuel. The gases are expressed in percentage volumes or measured bulk, and the numbers at the top refer to the height in feet above the twyer. The 1st table contains the results of Bunsen, the 2d those of Scheerer and Langberg.

tilized again when the heat reached that point; No. 2, by mixing with the coal the proportional quantity of ore and limestone, as used in the furnace; and No. 3, by beginning to heat from the opposite or open end, so that the gaseous products had to traverse a bed of ignited coals.

They further determined the composition of the coal, limestone, and ore, and determined what influence the two last would exert in increasing the quantity of carbonic acid. The coal was composed of

Carbon	74.83
Hydrogen.....	5.10
Oxygen.....	9.71
Nitrogen.....	0.18
Water.....	7.50
Ash	2.68
	100.00

By calculating the quantity of heat produced by each combustible substance, determined in the above analyses, it was ascertained that 81.54 pr. ct. of the fuel used at the Alfreton works was lost, and only 18.46 pr. ct. realized. From the third analysis, where the gaseous matters traversed ignited coke, it is shown that 83.45 pr. ct. of the heat is lost.

The size of the furnace at Alfreton, in which the experiments were performed, was 40 ft. high and 11 ft. wide in the boshes. The air was blown in at 626°, under a pressure of 6.75 inches mercury, and through a nozzle 2.75 in. diameter. The furnace receives 80 charges in 24 hours, each of which consists of calcined clay ironstone 420 lbs., coal 390 lbs., limestone 170 lbs., and the product of this amount is 140 lbs. pig-metal. The following table contains the analyses of the gases collected at different depths, during the working of the furnace:—

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Depth in ft. below the top...	5 ft.	8.	11.	14.	17.	20.	23.	24.	34.
Nitrogen.....	55-35	54-77	52-57	50-95	55-49	60-46	58-28	56-75	58-05
Carbonic acid.....	7-77	9-42	9-41	9-10	12-43	10-83	8-19	10-08	—
“ oxide.....	25-97	20-24	23-16	19-32	18-77	19-43	29-97	25-19	37-43
Light carburetted hydrogen .	3-75	8-23	4-57	6-64	4-31	4-40	1-64	2-33	—
Hydrogen.....	6-73	6-49	9-33	12-42	7-62	4-83	4-92	5-65	3-18
Olefiant gas.....	0-43	0-85	0-95	1-57	1-38	—	—	—	—
Cyanogen.....	—	—	—	—	—	—	trace	trace	1-34

Bunsen had previously shown that carburetted hydrogen is not formed by direct union of carbon and hydrogen, nor by the decomposition of water at the expense of coals; hence the carb. hydrogen developed at 24 ft., indicates that the coking goes on to that depth. This is explained by the size of the coal thrown in, often in 20 lb. pieces. The carburetted hydrogens and hydrogen are at a maximum at 14 ft. depth, where the coking is at a maximum. The gases could not be collected below 24 ft., because the iron tube entering the zone of fusion, was melted off. To collect the gas in the last column at 34 ft. depth, a hole was bored through the wall, 2½ ft. above the twyer, and the gas collected. Since there is no carbonic acid and no free oxygen found in the lowest part of the furnace, it is evident that all the oxygen of the blast is consumed near the twyer, and that carbonic oxide alone is there formed. The carbonic acid, therefore, found at 24 ft. depth, is due to the oxygen of the ore, and carbonic acid of the limestone. By estimating the varying quantity of oxygen in the gases compared with a given quantity of nitrogen, as that contained in the air, it was found that, while the proportion in the air is 79.2 : 20.8, in the furnace at the top of the bosh it was 79.2 : 27, and 2½ ft. above the twyer it was 79.2 : 22.8; whence their conclusion, that “In hot-blast furnaces fed with coal, the reduction of the iron ore and expulsion of carbonic acid from the limestone, takes place in the boshes of the furnace.” Since large masses of ore could not enter the crucible or hearth in the solid form, it is probable that the fusion of metal and slag takes place at or above the top of the hearth.

Application of Furnace gases. For purposes of heating, the gas should not be drawn from too great a depth, which would draw off the heat necessary for coking the coal; but when taken from the upper part, it is charged with the combustible products of distillation. The temperature attained by burning the escaping gases is 3083°, which, by a hot blast, may be raised to 3632°, while cast iron melts at 2192°; so that any required temperature is attainable, by burning these gases with hot air. Although these gases are used as the waste heat of the furnace, yet there can be no doubt that they are employed to a limited extent, as compared to what they are capable of being applied to; and there is every reason to believe that, with the best arrangements hitherto made, one half of the heat derivable from the fuel of a furnace is lost.

The ammonia evolved in the gases might easily be saved, by conducting the gases through a chamber containing muriatic acid, and evaporating the solution by a portion of the inflated gases; or a portion of it may be

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collected in a liquid state with water, as carbonate of ammonia. From the last column of the analyses it will be observed that cyanogen is contained in quantity in the gases taken from the boring a short distance above the twyer. The gases issuing from an iron tube inserted in the bore were richly charged with cyanide of potassium. It was ascertained experimentally, that at least from every 100 pts. of coa. there was obtained 0.778 cyanide of potassium, which would make 224.7 lbs. daily generated in the furnace. Upon examination it was found that the iron ore contained 0.743, or ¾ of 1 pr. ct., and the coal 0.07 pr. ct. potassa. It is well known that ammonia passed over carbon at a high temperature forms cyanogen, but every trace of ammonia must have been removed from the coal before it reaches this part of the furnace. They proved by direct experiment, that pure nitrogen passed over pure potash and pure charcoal at a high heat, yielded abundance of cyanide of potassium, while carbonic acid passed over the same yielded none. Hence the conclusion, “that a considerable quantity of cyanide of potassium is formed in iron furnaces immediately above the point where the blast comes in contact with the glowing fuel, and that its formation is owing to a direct union of carbon with potassium, and with nitrogen of the air.” Cyanide of potassium is volatile at high temperatures, and lends its influence to reduce the ores of the furnace. It is probable that the excess of oxygen at the boring, 22.8, over that in the air, 20.8, is due to the reduction of potassa in the zone of high heat above the twyer. See Rep. British Assoc. 1845.

IRON AND ITS NON-SALINE COMPOUNDS.

1. *Iron.* The metal is best obtained in a perfectly pure state by the reduction of pure oxide of iron by hydrogen; in which but a low temperature is required, if the iron is to be obtained pulverulent. Reduced at too low a temperature, and even cooled in hydrogen, it takes fire upon exposure to the air. (*Magnus.*) It is employed to a limited extent in medicine. The general properties of pure iron have been given under bar iron.

Sym. Fe (Ferrum) Eq. 28. Berzelius' last determination is 350.527.

2. *Oxides.* a. *Protoxide of Iron.* Ger. Eisenoxydul. Unknown in a dry state. Form. FeO, containing 77.78 pr. ct. iron. The hydrate precipitates, by adding potassa to a solution free from peroxide, as white flocculae, which it is exceedingly difficult to dry without oxidation. It has a powerful affinity for oxygen, passing into oxide-peroxide, and then to hydrous peroxide in the air. It is a very strong base.

Its salts are light green when hydrous, white

when dry; those insoluble in water are soluble in muriatic acid; when heated they give off their acid, if volatile, leaving peroxide, or oxide-peroxide, or with organic acids metallic iron. From the neutral salts in a closed vessel, zinc throws down oxide and metallic iron. Sulphuretted hydrogen will throw down sulphuret of iron, only from a salt containing organic acid, and not in excess; the alkaline sulphuret precip. sulphuret of iron, insoluble in an excess of the precipitant, but a persulphuret of ammonium dissolves a little. The caustic, carbonated, and bicarbonated alkalis precipitate hydrated or carbonated oxide, which becomes greenish and brown from oxidation. Carbonated alkaline earths do not precipitate oxide salts, except by continued exposure to the air, or by heat. (*J. C. B.*) Phosphate and arseniate of soda give white precipitates, the former becoming bluish, the latter greenish in the air. Yellow prussiate of potash gives in pure solutions a white precipitate, changing to green and blue, or, if they contain peroxide, a blue at once; the red prussiate gives a blue at once, even if exceedingly minute quantities of oxide be present. Oxalic acid or binoxalates color the solutions yellow, and deposit after some time a yellow oxalate, which is thrown down at once by neutral oxalate. A solution of galls does not change the color of the solutions, if free from peroxide; but exposure to the air produces a violet-black. The presence of protoxide of iron in mineral silicates, may often be inferred from their green color.

b. Peroxide. Sesquioxide. Ger. Eisenoxyd. Form. Fe_2O_3 , containing 70 pr. ct. iron. It occurs native as *SPECULAR IRON*. See also the ores of iron, at the beginning of this article. It is formed by dissolving iron in nitric acid, evaporating, and igniting; by roasting the metal or its oxides in the air; by heating the hydrate; by strongly calcining the sulphate. It has a red or brownish red color, and after strong ignition is almost black. In contact with carbon at a high heat, it is reduced when in lump to the metallic state, both by carbonic oxide and probably by cementation. It is also reduced by hydrogen and carbonic oxide, and is changed by sulphur into sulphuret.

Hydrate of the peroxide is formed by exposing the metal to a moist air; of a russet color, *rust*, with the form. $2\text{Fe}_2\text{O}_3, 3\text{HO}$; or by precipitating a soluble salt by carbonated or caustic alkali, of a brown color, which when dried at 212° has the formula $\text{Fe}_2\text{O}_3, 2\text{HO}$. Its water is easily expelled by heat. The *Salts* are formed by dissolving the hydrate in an acid (the ignited oxide dissolves with difficulty); or by the joint action of another acid with nitric acid or chlorine on the metal or a lower oxide. The anhydrous salts are generally white, the solutions yellow or brown. A characteristic of the neutral soluble salts (1 equiv. oxide + 3 equivs. acid) is, either by heating them to boiling, especially when dilute, or by a portion of alkali, or by the action of alkalino-earthly carbonates, to be reduced to basic salts of a darker color, which are either less soluble, or wholly insoluble in water. Sulphurous acid, copper and other metals, and

sulphuretted hydrogen reduce the sesqui to the protoxide; the last precipitates sulphuret of iron from a weak acid, until the acid greatly preponderates. Sulphuretted alkalis precipitate black sulphuret, even to a dilution of 100,000 pts. water; and exhibit a grayish green color in a dilution of 400,000 pts. water. Brown, hydrated sesquioxide is wholly precipitated from the solutions by caustic and carbonated alkali, and by carbonates of lime, baryta, strontia, magnesia, zinc, manganese, and copper in the cold. Phosphates and arseniates throw down white salts; yellow prussiate of potash precipitates Prussian blue; red prussiate does not affect them, but precipitates the blue, if the least trace of protoxide be present. Sulpho-cyanhydric acid and its salts (rhodanides) color iron salts blood-red or orange, according to the concentration; when diluted to 800,000 pts. water, pale orange. Meconic and indigotic acids and their salts color the per-salts of iron red. Tincture of galls gives a blue black coloring and precipitate, the former appearing in 300,000 pts. water. Succinic acid and salts give a light brown, voluminous precipitate, in neutral solutions.

3. Magnetic oxide. It occurs as a mineral. It is also formed by passing vapor of water over ignited iron or slag; by burning iron in oxygen; fusing chloride of iron and carbonate of soda at a low red heat, and extracting the soluble salts with water. Its formula is $\text{Fe}_3\text{O}_4 = \text{FeO} + \text{Fe}_2\text{O}_3$, containing 72.41 pr. ct. metal. Hydrated magnetic oxide is precipitated from a solution of the same oxide in muriatic acid, by ammonia, and may be washed without higher oxidation. Both the hydrated and anhydrous oxides are magnetic.

4. Ferric acid is known only in combination with alkalis. It is formed by igniting to full redness 1 pt. powdered peroxide or metal with 4 pts. saltpeter, or the peroxide with potassa, powdering and dissolving in water. The solution is also made by passing chlorine through a strong solution of potassa, containing oxide of iron, until the latter dissolves with a red color. Its solutions are purplish red, and easily decomposed, either by standing, boiling, and by all deoxidizing substances.

Sulphurets. *1. Protosulphuret.* Formed by mixing iron filings or turnings with $\frac{3}{4}$ its weight of sulphur, and projecting them into an ignited earthen crucible; by heating the mixture in a covered crucible; by holding a piece of sulphur against a bar of iron heated to whiteness; by strongly igniting pyrites mixed with a due proportion of iron. It should be heated to fusion. It is dull yellow, with a metallic lustre, generally magnetic, and its formula is FeS , containing 63.64 pr. ct. metal. By roasting in the air at a gentle heat, it is converted into a mixture of protosulphate and peroxide of iron, by a higher heat into peroxide; it dissolves readily in dilute muriatic or sulphuric acid, evolving sulphuretted hydrogen; when heated in chlorine, it forms chloride of iron and of sulphur; it fuses to a perfect liquid at a high temperature, a bright red heat, but mixed with alkali forms a much more fusible mixture, at a low red heat. The same sub-

stance is prepared in the dry way, probably combined with water, by precipitating a proto-salt of iron with sulphhydrate of ammonium. It is black, and very subject to oxidation, yielding sulphuretted hydrogen abundantly by feeble acids.

2. *Sesquisulphuret*. Fe_2S_3 . Formed by heating iron, with excess of sulphur, to a low red heat; by passing sulphuretted hydrogen over peroxide of iron until water ceases to be formed. It is grayish yellow, oxidable in the air by roasting, leaving peroxide; spontaneously, when formed by the second method, leaving peroxide and sulphur; evolves sulphuretted hydrogen by sulphuric or muriatic acid, forming a solution of a protosalt, and leaving bisulphuret of iron. The hydrate is precipitated black from a persalt of iron, by alkaline sulphuret.

3. *Lisulphuret*. Exists in nature as **IRON PYRITES**. Form. FeS_2 , containing 46.67 pr. ct. iron. It is formed by heating iron or a lower sulphuret, with an excess of sulphur, to a heat much below redness; by passing sulphuretted hydrogen over oxide, hydrate, carbonate, or a lower sulphuret of iron, below redness, until it ceases to increase in weight. By heating in a close vessel or in the air, it behaves like the preceding. By slow oxidation in presence of moisture, free sulphuric acid is formed beside protosulphate of iron, and hence the corrosive action on steam-boilers of waters flowing from the coal mines of Pottsville, &c., in which there is often a considerable quantity of free sulphuric acid. White or spar pyrites is very liable to this disintegration, and this result is usually ascribed to the presence of protosulphuret; but from the presence of free sulphuric acid, it appears that a higher sulphuret also disintegrates. (*J. C. B. and C. Morfill*.) This agrees with an observation of H. Rose, that an effloresced vitriol gave him a solution, which did not cloud by a little potassa or by long exposure to the air (from free sulphuric acid?), and a residue containing free sulphur. There is no doubt that a lower sulphuret oxidizes more readily, and hence the heating or roasting of pyritous slates in the manufacture of **ALUM**.

Phosphurets. Phosphuret is formed by throwing phosphorus on ignited iron filings; by igniting iron with dry phosphoric acid and a little charcoal; by igniting phosphate of iron with $\frac{1}{4}$ as much lampblack; by igniting 8 pts. iron filings, 10 pts. bone-ash, 5 pts. quartz-sand, and 1 pt. charcoal powder, until silicate of lime fuses. (*Wöhler*.) It is white, metallic, granular, brittle, more fusible than cast iron. It oxidizes with difficulty to phosphate, is not attacked by cold acids, even nitromuriatic, and slowly by heated aqua-regia. Form. Fe_3P . Another phosphuret is formed by passing phosphuretted hydrogen over pyrites slightly heated. There are several unimportant sulphocarbonates and sulphophosphates of iron, with the formulæ FeS , CS_2 ; Fe_2S_3 , CS_2 ; FeS , PS ; 2FeS , PS ; 2FeS , PS_2 .

Carburets. Steel and cast iron are carburets, but not of uniform composition; they contain, however, definite carburets. Fe_4C appears to be a saturated cast iron, and is obtained by

repeatedly fusing iron and charcoal together, or iron with prussiate of potash. FeC_2 is obtained by heating cyanide of iron apart from the air. FeC_3 is supposed to remain together with graphite, upon dissolving cast iron or steel in acid.

Alloys. By igniting iron with the earths and charcoal, several alloys have been formed, whiter, less ductile, and more oxidable than iron; the alloy of potassium, as accidental product in preparing potassium, is malleable, and so soft as to receive an impression from the nail. With columbium iron forms an alloy harder than glass, and difficult to break. With molybdenum, bluish gray, hard, brittle, granular, magnetic. With manganese, whiter, more brittle, less magnetic than iron; the compound with steel is brittle in the cold, malleable when hot. Iron unites with some difficulty with zinc, lead, tin, copper, mercury, silver. With most metals its alloys are brittle. With nickel it unites readily in many proportions, forming a less malleable, magnetic metal, and less liable to rust. 11 pts. gold and 1 pt. iron give a yellow, malleable, hard alloy; 1 gold + 4 iron is silver-white. An alloy of 99 iron + 1 platinum is not attacked by common nitric acid. Iron also unites with palladium and rhodium. Sheet tin is sheet-iron dipped into melted tin, a portion of which adheres to the surface as tin, and another enters into the iron and alloys with it. Iron coated with zinc constitutes galvanized iron; the zinc and tin protects the iron more or less from rust.

SALTS.

Haloid Salts. 1. *Chloride of Iron*. By dissolving an excess of iron in muriatic acid, and evaporating apart from the air, this salt crystallizes in light bluish rhombs, which may be dried at 110° — 120° , and preserved in bottles. They become green by exposure to the air, deliquesce, dissolve in alcohol and in 0.68 pts. water, and absorb nitric oxide, becoming dark brown; their formula is $\text{FeCl} + 4\text{HO}$. By evaporating the solution to dryness apart from the air, dry chloride is formed, fusible and volatile at a strong red heat. It may also be formed in white, pearly scales, by passing dry muriatic gas over ignited iron filings.

2. *Perchloride*. Is obtained by dissolving iron in nitro-muriatic acid, or the peroxide in muriatic acid, and evaporating to a syrupy liquid. It crystallizes in two forms, one with the form. $\text{Fe}_2\text{Cl}_3 + 12\text{HO}$, which by fusion and evaporation, with the addition of a little muriatic acid, forms $\text{Fe}_2\text{Cl}_3 + 5\text{HO}$. The former is orange-yellow, the latter dark reddish yellow. The anhydrous perchloride, formed by passing chlorine over heated iron, sublimates in metallic, black plates. The perchloride is soluble in alcohol and ether, which tend to reduce it to the chloride. By evaporation and heating in the air, a basic perchloride or oxy-chloride is formed, which is either soluble, as when hydrated peroxide is added to perchloride, or insoluble, as when the simple chloride solution oxidizes in the air.

3. The two chlorides, with chloride of potassium, yield double salts, the latter of which

has the form. $2 \text{KCl}, \text{Fe}_2\text{Cl}_3 + 2 \text{HO}$. The chloride of iron and ammonium is formed by mixing hot and strong solutions of 1 pt. simple chloride and 4 pts. salammoniac, and keeping them in a closed vessel to crystallize; by boiling a saturated solution of salammoniac with iron filings, and evaporating apart from the air, to crystallize. It is colorless, greenish or yellowish, very soluble in water.

4. *Bromide*. The dry bromide, made by passing bromine vapor over gently-ignited iron wire, fuses with violent ignition to a yellowish crystalline mass. The aqueous salt is made by dissolving the preceding in water, or by the action of an aqueous solution of bromine or of bromohydric acid on iron. By evaporation it leaves the dry salt; and by heating the latter, perbromide sublimes and leaves peroxide. The crystals are $\text{FeBr} + 6 \text{HO}$.

5. *Perbromide*. Formed by dissolving perhydrate of iron in bromohydric acid; gives a dark brownish solution, and by evaporation forms an insoluble oxybromide. By evaporating a solution of iron in an excess of bromine water, to dryness, it forms a brownish red mass, fusible and partly volatile, without decomposition.

6. *Iodide* is formed by heating iron and iodine together; or by digesting 1 pt. iron with 4 pts. iodine and some water, and evaporating in a flask containing iron wire. (The evaporation may be conducted in a porcelain capsule, with clean wire or turnings, until a drop of the solution taken out, solidifies; it is then poured out on a plate of glass or porcelain, broken up, and kept in vials.) The former, by heat, is brown, fusible and volatile at a high heat; the latter is steel-gray, and fuses at 350° . By evaporating the aqueous solution in a water-bath, it yields dark, olive-brown crystals, with the form. $\text{FeI} + 5 \text{HO}$. The solution is also made by a cold digestion of 1 pt. iron with 2 pts. iodine, and water. The tendency of this salt to oxidize is prevented, by evaporating its solution with 2 pts. sugar (to 1 iodine), to a syrup.

7. *Fluoride*. Formed by dissolving iron in fluohydric acid; yields white, rectangular tables, not very soluble in water. The perfluoride, formed from peroxide and the same acid, yields flesh-red crystals. Both salts yield double salts with alkaline fluorides, difficultly soluble in water.

Oxysalts. 1. *Protosulphate of Iron*. Syn. *Copperas*, Green vitriol. *Prep*. 1. By dissolving iron, bar or cast iron, in dilute sulphuric acid, and evaporating to crystallization. $\text{Fe} + \text{SO}_3, \text{HO} = \text{FeO}, \text{SO}_3 + \text{H}$. 2. By partially roasting iron pyrites, exposing to moist air, extracting with water, and crystallizing. 3. As a secondary product in the manufacture of **ALUM**.

Prop. It forms light bluish green or greenish blue crystals, with the formula $\text{FeO}, \text{SO}_3 + 7 \text{HO}$, containing 27.27 FeO , + 30.30 SO_3 + 42.43 HO . Therefore 100 pts. of strong oil of vitriol require 71 pts. iron, or 100 pts. iron require 175 pts. oil of vitriol, to make copperas; but if the iron be partially rusted, or the oil of vitriol be not concentrated, more of that substance is required. The commercial

article is usually yellowish, from the presence of a persalt of iron. The presence of copper is easily detected, by holding a bright piece of iron for a moment in the solution, when the copper coats it with its characteristic red color. To free copperas solution from both these, acidulate it with a little sulphuric acid, and put in metallic iron, which removes the copper, and deoxidizes or precipitates peroxide. To free it from copper, arsenic, lead, copper and tin, and to reduce the iron to protoxide, pass sulphuretted hydrogen through the solution, and let it stand for a day, to let these impurities settle. Zinc, manganese, and alumina cannot be readily removed. If crystallized from an acid solution, it keeps well, even if not well dried; but if from a nearly neutral solution, the crystals must be well dried, to keep.

It is soluble in 1.6 cold, and in 0.3 boiling water. The solution is precipitated by oil of vitriol or alcohol; by exposure to air, it gradually deposits basic persulphate, while neutral persulphate remains in solution. The solution absorbs nitric oxide, becoming dark olive, and if then heated, persulphate is formed. By heating the crystals slowly, apart from the air, the white anhydrous salt is obtained; by heating rapidly in the air, a basic persulphate is formed, in quantity proportioned to the length of roasting; by heating the dried salt highly in a retort, peroxide remains (colcothar), while fuming sulphuric acid passes over.

By evap. the solution of copperas at 176° , a salt crystallizes, containing 4 HO ; by mixing muriatic acid with the solution, copperas first crystallizes out, and then a salt with 3 HO ; by adding oil of vitriol, and evaporating over oil of vitriol, copperas first separates, followed by the salt with 4 HO , then a salt of 2 FeO , 3 SO_3 + 7 HO , and lastly FeO, SO_3 + 2 HO ; by heating copperas to 280° in vacuo, FeO, SO_3 + HO remains, and this last equiv. water requires a heat of 530° , for expulsion.

Sulphate of iron forms double salts with sulphates of potassa and ammonia, the former by dissolving iron in bisulphate of potassa, the latter by a direct mixture of the salts; each contains 6 HO .

2. *Persulphate of Iron*. Sesquisulphate. $\text{Fe}_2\text{O}_3, 3 \text{SO}_3$. It is conveniently made by acting on peroxide of iron in powder (colcothar or red hematite), by oil of vitriol, 12 pts. of the former to 7 of the latter; by dissolving 14 pts. copperas in water, adding 5 pts. oil of vitriol, and while heating to boiling, adding nitric acid portionwise, until a drop of the liquid ceases to form Prussian blue with red prussiate of potassa. A dark brown solution, which may be evaporated to a brown, resinous mass, which may be further dried to a dirty white powder, the anhydrous sulphate. The latter is very slowly deliquescent, dissolves slowly in water, and when diluted and boiled, deposits the $\frac{1}{2}$ neutral salt; it is soluble in alcohol. The $\frac{2}{3}$ neutral salt, $\text{Fe}_2\text{O}_3, 2 \text{SO}_3$, is obtained by adding lime or chalk to the neutral salt in strong solution, as long as the precipitate ($\frac{1}{3}$ neutral) redissolves, and filtering rapidly. The $\frac{1}{2}$ neutral salt, $\text{Fe}_2\text{O}_3, \text{SO}_3$ + 3 HO , obtained by adding carbonated alkali until it be-

gins to precipitate, and then boiling, is light reddish yellow powder. The $\frac{1}{8}$ neutral salt, $2\text{Fe}_2\text{O}_3, \text{SO}_3 + 6\text{HO}$, of a yellowish brown color, is obtained by precipitating the neutral with insufficient alkali, or by exposing a solution of copperas to the air. The $\frac{1}{10}$ salt, $3\text{Fe}_2\text{O}_3, \text{SO}_3 + 4\text{HO}$, precipitates on boiling a dilute neutral solution. Beside these there are several mineral persulphates, given under **COQUIMBITE**.

The persulphate forms double salts with sulphate of potassa and ammonia. The former, potassa-iron-alum, is made by dissolving 80 pts. peroxide of iron in 147 pts. of oil of vitriol, to make the neutral persulphate of iron as above directed; or by oxidizing 278 pts. copperas with 49 oil of vitriol, by nitric acid or chlorine; and to each of these add 87 pts. sulphate of potassa. It is also obtained by warming together 14 pts. powdered copperas, and 5 pts. saltpeter (or $4\frac{1}{2}$ pts. soda-saltpeter), with $7\frac{1}{2}$ pts. oil of vitriol, dissolving in 4 pts. water below boiling, and filtering. It crystallizes in pale violet, or colorless 8-hedra, which are apt to be tarnished brownish externally; soluble in 5 pts. cold water. Form. see under **ALUMS**. It has a tendency, when heated, to pass into basic double salts. The ammonia-iron-alum, obtained by direct mixture, crystallizes in the same form, and has the general formula of alum.

3. *Protophosphate*. Made by precipitating copperas with common phosphate of soda; is white, changing to a dirty bluish green in the air; fusible, and congeals to a crystalline mass. There is also an acid and a basic salt; the latter is **VIVIANITE**. The hypophosphite is made by the action of the acid on iron, apart from the air. The phosphite is precipitated from copperas solution, apart from air, by a solution of trichloride of phosphorus, neutralized by ammonia.

4. *Perphosphate* is precipitated from perchloride by phosphate of soda, white, soluble in 1500 pts. water, readily in mineral acids, becoming brownish by heat, fusible, and reducible to phosphuret by coal. Caustic potassa or soda extracts most of the phosphoric acid, and all of it, when joined with sulphammonium; ammonia acts similarly, but if an excess of phosphate of soda be present, the precip. gradually dissolves with a brown color. The phosphate, dissolved in muriatic acid, is boiled with a little sulphite of soda, neutralized by carbonate of soda, and boiled with caustic potassa or soda until the precipitate is black and granular; the filtrate will now contain all the phosphoric acid. (*Fresenius*.) It is insoluble in acetic acid in the cold, unless a large proportion of iron be present. Phosphate, and probably several phosphates, occur frequently in iron ores; see **Metallurgy of IRON**.

5. *Pernitrate*. Iron dissolves readily in somewhat diluted nitric acid, forming partly a protosalt, which, however, readily passes into the persalt. The latter may be evaporated to a syrup, but after drying loses acid by heat, becoming basic, and then oxide. If this concentrated solution be mixed with 5 vols. water, heated gradually to boiling, and allowed to

cool, upon the addition of nitric acid an ochrey-yellow basic salt separates, which is soluble in water. If this be rapidly filtered off, the filtrate evaporated and left to itself in a close vessel, it forms colorless or yellowish cubes. A brown basic salt separates on boiling the neutral, dilute solution.

6. *Perchlorate, &c.* A *perchlorate* of protoxide in colorless needles, is obtained by double decomposition with copperas and perchlorate of baryta, and evaporation. *Bromate* of peroxide is formed by solution of the hydrate in the acid. *Iodate* of peroxide precipitates as a brownish basic salt, on adding iodated alkali to copperas; a yellowish white acid salt is formed by adding iodated alkali to perchloride of iron, or to ammonia-iron-alum.

7. *Carbonate* of protoxide occurs in nature as **SPARRY IRON**. The artificial salt is a mixed carbonate and hydrate. To make it, the copperas should be free from peroxide, and the water used for dissolving it and the carbonated alkali, should be freed from air by boiling; the precipitation should take place in a flask or bottle, be suffered to settle, and be washed in the same vessel, and be filtered as much apart from the air as practicable. The precipitation is generally made in the cold with an excess of carbonate of soda; but **Wittstein** and **Wilkins** perform it hot, and boil for $\frac{1}{2}$ hour. In the latter case there should not be much excess of alkali. Bicarbonated alkali is thought to give a closer precipitate. The filtration is sometimes performed in an atmosphere of carbonic acid or of ether-vapor. When well prepared, it is greenish white or dark green. It has a strong tendency, even when dry, to lose its carbonic acid, and to oxidize; but if mingled, while fresh and moist, with sugar to a syrup, it may be kept unchanged. The bicarbonate (contained in natural chalybeates) may be imitated by dissolving the fresh carbonate in carbonated (soda) water. The carbonate is one of the useful salts of iron used in medicine.

8. *Borate* of protoxide, made by double decomposition from copperas and borax, is light greenish. Borate of peroxide is a yellowish, insoluble powder. Both are fusible by heat.

9. *Silicate*. Silicates of iron almost invariably accompany iron ores, and many of them have a definite composition. Protoxide of iron colors glass green; peroxide, orange or yellow; and these colors in minerals frequently indicate the degree of oxidation. A silicate formed in making bar iron has the formula $6\text{FeO}, \text{SiO}_3$. Other slags have the form $3\text{FeO}, \text{SiO}_3$ and $3\text{FeO}, 2\text{SiO}_3$. Among minerals there are silicates of protoxide, anhydrous, **CHALCOPHANEITE** and **FAYALITE**; hydrated, **SIDERO-SCHISTOLITE**; silicates of peroxide, hydrous, are **NONTRONITE** and **HISINGERITE**. Many others contain either or both silicates, replacing magnesian bases or alumina; as **GARNET**, **AUGITE**, &c.

IRON. Min. See **AEROLITE**.

IRON ALUM. Min. Yellowish white fibres, or efflorescence of a silky lustre and a sweetish, astringent taste; with a form. similar to the **ALUMS**.

IRON FOAM. See **SPECULAR IRON**.

IRON PYRITES. There are three varieties of this pyrites: the common, spear, and magnetic pyrites.

1. *Iron Pyrites.* Syn. Marcasite, Mundic. (?) *Ger.* Eisenkies, Schwefelkies.

Descrip. Cryst. Regular. Pl. VIII., figs. 1, 4, 8, and their combinations. Of the hemiforms, figs. 12, 13, 17, and their combinations. Fig. 17 is a very frequent form alone, and with cubic and 8-hedral faces. Cleavage imperfect parallel to 6 and 8-hedron. It also occurs fibrous, granular. $H. = 6 - 6.5$. $G. = 4.9 - 5.1$. Color various shades of bronze-yellow, often externally chestnut-brown; lustre metallic, usually splendid; opaque; streak brownish; brittle with conchoidal, uneven fracture; strikes fire with steel, whence its name, from $\pi\upsilon\varsigma$, fire.

Chem. Rel. In a closed tube it gives sulphur and sulphurous acid; in an open tube more sulphurous acid, and fuses on coal to a black, magnetic bead. Scarcely attacked by muriatic acid, soluble in nitric, with separation of sulphur. Formula FeS_2 .

Local. &c. Its localities are exceedingly numerous, in every kind of rock, and is even of modern origin. It is used for the manufacture of sulphate of iron and oil of vitriol, alum, &c. See ALUM and SULPHUR. It is also of importance in concentrating copper ores, some gold ores, silver ores, &c.

2. *Spear Pyrites.* Syn. White P., Hepatic P., Radiated P., Cockscomb P. *Ger.* Kammkies, Leberkies, Spärkies.

Descrip. Cryst. Right Rhombic, presenting a vert. prism, parallel to which it cleaves, and many horizontal prisms; compounded on the vert. prism, 5 individuals often uniting into a flat pentagon. $H. = 6 - 6.5$. $G. = 4.7 - 4.9$. Pale bronze-yellow, sometimes nearly white; metallic; brittle with uneven fracture, and grayish or brownish black streak. Behavior and formula the same as common pyrites. It may be a compound of magnetic and common pyrites, or a hydrate, as Glocker found water in the so called Wasserkies. It is less abundant than common pyrites, and is more subject to disintegration.

3. *Magnetic Pyrites.* Magnetkies. Cryst. Hexagonal, cleaving parallel to the end-plane; usually amorphous. $H. = 3.5 - 4.5$. $G. = 4.63$. Color reddish-bronze; metallic; brittle, with a grayish black streak; slightly magnetic, more easily disintegrated. Yields no sulphur in a closed tube, and is soluble in muriatic acid, with evolution of sulphuretted hydrogen; otherwise behaves like the preceding. Form. $9 FeS + Fe_2S_3$ to $FeS + Fe_2S_3$.

IRON SINTER. *Min.* *Ger.* Eisensinter, Eisenpecherz. Reniform and massive. $H. = 2$. $G. = 2.2 - 2.4$. Yellowish brown, blood-red, white; vitreous, translucent, opaque; streak yellow, white. It yields water, sulphuric acid, and arsenic, and after removing the last with mic. salt and tin, it shows copper. Probable form. $2 Fe_2O_3, AsO_5 + 12 HO$, in which the SO_3 is omitted. From Freiberg.

ISATIN. ISATIC ACID. See INDIGO.

ISATIS TINCTORIA. See WOOD.

ISERINE. See TITANIC IRON.

ISINGLASS. See GELATIN.

ISOMERISM. *Chem.* Two bodies may each be composed of the same number of equivalents of the same elements, and yet possess different properties. Thus we have red and black sulphuret of mercury, composed of exactly the same amounts of sulphur and mercury. We have also a red iodide of mercury, formed by triturating iodine and mercury with a little water; when heated it sublimes of a yellow color, and by touching the latter with a needle, it rapidly changes again to the red. In like manner phosphoric acid exhibits three different properties, and seems to be capable of uniting either with 1, 2, or 3 equivs. of base. Among organic bodies, we have tartaric and racemic acids, having the same formula, $C_4H_4O_6$; oil of turpentine, lemon, &c., C_4H_8 ; which are composed of the elements equal in nature and proportion, but yet the compounds show different properties.

One cause of isomerism is doubtless a different arrangement of the elements. Thus, acetic ether and formic ether have the ultimate composition $C_6H_8O_4$, but it can be proved that the former has the formula $C_2H_3O + C_4H_5O_3$, and the latter $C_4H_5O + C_2HO_3$; and we know of no method by which one can be converted into the other. Cyanate of ammonia, NH_4O, C_2NO , has the same ultimate formula as urea, $C_2N_2H_4O_2$, but they are combined in a different manner. This mode of combination has been termed *metameric*.

Another apparent cause of isomerism is the absolute number of equivalents of each element present in a compound. Thus, olefiant gas is by ultimate analysis CH , but from specific gravity and for other reasons, its formula should be either C_2H_2 or C_4H_4 ; amylene $C_{10}H_{10}$; camphen is written $C_{20}H_{16}$, and copaiven $C_{30}H_{24}$. In like manner some would write phosphoric acid $PO_5, P_2O_{10}, P_3O_{15}$, although this view is doubtful. Such bodies are termed *polymeric*, but they are only isomeric in reference to ultimate analysis.

A third source of isomerism is the property possessed by some elements of exhibiting different properties, which they sometimes carry through their compounds. The diamond and plumbago are familiar instances. There is a more soluble and less soluble tellurous, and a corresponding more and less soluble telluric acid. Oxide of tin precipitated, and made by nitric acid from the metal, exhibit different properties. Such bodies are said to be in a different *allotropic* condition.

ISOMORPHISM. *Chem.* Crystallized bodies assume forms referrible to one of the 6 systems (see CRYSTALLOGRAPHY), and many different bodies must therefore belong to the same system. But it has been found that certain elements and certain compounds, when combined with the same body and in the same proportion, assume the same form. These elements or compounds may replace each other in equivalents in compounds without an alteration of their crystalline form, apart from slight variations in the angles. In some cases the elements are isomorphous, and show their corresponding compounds isomorphous. In others only certain corresponding compounds appear to be isomorphous, and replace

ISOMORPHISM.

each other in equal equivalents; or in some cases in unequal equivalents. In illustration of the first case, antimony and arsenic both crystallize in the hexagonal system, with the same acute rhombs; arsenious acid, AsO_3 , and antimonious oxide, SbO_3 , both crystallize in the regular system, and Mitscherlich has shown that some of their salts with the same base are isomorphous. In the second case, magnesia, oxides of iron, manganese, copper, &c., may and do replace each other in their carbonates, silicates, sulphates (with the same amount of water), &c. In the third case, the corresponding salts of ammonia with 1 equiv. water, and potassa, have the same form; so also KO , ClO_7 and KO , Mn_2O_7 are isomorphous.

The following table groups together many simple and compound bodies, which have been shown to be isomorphous. They are arranged according to the system in which they crystallize.

Regular system.

C, P, Ti, Au, Ag, Cu, Bi, Pb, Cd, Fe, K.
 CoAs , CoS , ZnS , PbS , AgS , KCl , NaCl , LiCl ,
 NH_4Cl , AgCl , KBr , NaBr , KI , NaI , KF ,
 NaF , CaF .
 Cu_2O , Cu_2S , Cu_2Cl , Hg_2Ag .
 FeS_2 , $\text{CoAs} + \text{CoS}_2$ (cobalt glance), or $(\text{CoAs}_2 + \text{CoS}_2)$ Berz.)
 AsO_3 , SbO_3 .
 MgO , Al_2O_3 and MgO , Fe_2O_3 (spinel); ZnO ,
 Al_2O_3 (gahnite); FeO , $\text{Fe}_2\text{O}_3 + \text{ZnO}$, Mn_2O_3
(franklinite and dysluite); FeO , Fe_2O_3 (magnetic iron); FeO , Cr_2O_3 (chromic iron).
 BaO , NO_3 ; SrO , NO_3 ; PbO , NO_3 .
 NH_4Cl , PtCl_2 ; NH_4Cl , IrCl_2 ; KCl , PtCl_2 ;
 KCl , IrCl_2 ; KCl , OsCl_2 .
The alums RO , $\text{SO}_3 + \text{R}_2\text{O}_3$, $3\text{SO}_3 + 24\text{HO}$.

Quadratic system.

TiO_2 (rutile); SnO_2 (tin ore).
 NiO , SO_3 , 7 HO; NiO , SeO_3 , 7 HO; ZnO ,
 SeO_3 , 7 HO.
 2NH_3 , AgO , SO_3 ; 2NH_3 , AgO , SeO_3 ; 2NH_3 ,
 AgO , CrO_3 .
 NH_4O , PO_5 , 2 HO; NH_4O , AsO_5 , 2 HO; KO ,
 PO_5 , 2 HO; KO , AsO_5 , 2 HO.
 PbO , CrO_3 ; PbO , MoO_3 ; PbO , WO_3 ; CaO , WO_3 .

Right Rhombic.

S; I. AsO_3 ; SbO_3 .
 FeS_2 (radiated pyrites); $\text{FeAs} + \text{FeS}_2$ (arsenical pyrites), or $(\text{FeAs}_2 + \text{FeS}_2)$ Berz.)
 BaO , CO_2 ; SrO , CO_2 ; PbO , CO_2 ; CaO , CO_2
(arragonite).
 BaO , SO_3 ; SrO , SO_3 ; PbO , SO_3 .
 NH_4O and KO , each with ClO_7 and Mn_2O_7 .
 NaO and AgO , each with SO_3 and SeO_3 .
 KO , SO_3 ; KO , SeO_3 ; KO , CrO_3 ; KO , MnO_3 .
 ZnO , SO_3 , 7 HO; NiO , SO_3 , 7 HO; MgO , SO_3 ,
7 HO; MgO , SeO_3 , 7 HO.
 NaO , PO_5 , 4 HO; NaO , AsO_5 , 4 HO.

Oblique Rhombic.

FeO , TaO_3 (columbite); FeO , WO_3 (wolfram). S.
 CaO , SO_3 , 2 HO; FeO , SO_3 , 2 HO; CaO ,
 SeO_3 , 2 HO.

ISOPYRE.

FeO , SO_3 , 7 HO; CoO , SO_3 , 7 HO; CoO , SeO_3 ,
7 HO; MnO , SO_3 , 7 HO.
 ZnO , SO_3 , 6 HO; MgO , SO_3 , 6 HO; CoO , SO_3 ,
6 HO.

Triclinic.

MnO , SO_3 , 4 HO; ZnO , SeO_3 , 4 HO.
 CuO , SO_3 , 5 HO; MnO , SO_3 , 5 HO.

Hexagonal.

As, Sb, Te, C ?.
 3AgS , AsS_3 ; 3AgS , SbS_3 .
 Al_2O_3 ; Fe_2O_3 ; Cr_2O_3 ; FeTiO_3 .
 CaO , CO_2 ; MgO , CO_2 ; FeO , CO_2 ; MnO , CO_2 ;
 ZnO , CO_2 .
 CaCl_2 , $3(3\text{CaO}, \text{PO}_5)$; PbCl_2 , $3(3\text{PbO}, \text{PO}_5)$;
 PbCl_2 , $3(3\text{PbO}, \text{AsO}_5)$.

It appears from the above that a majority of the elements which have been observed crystallized, take the regular form. But many of the bodies assume two forms,—are dimorphous, as sulphur, carbon, iron pyrites, sulphate of nickel, &c. Antimonious oxide and arsenious acid are both dimorphous and isomorphous. We can determine the following seven groups of isomorphous bodies:—

MgO	K O	Al_2O_3	Cr O
Ca O	Na O	Fe_2O_3	W O ₃
MnO	NH_4O	Mn_2O_3	MoO_3
Fe O	L O	Cr_2O_3	TaO_3
Co O			
Ni O	Ba O	S O ₃	P O ₅
Cu O	Sr O	Se O ₃	As O ₅
Zn O	Ca O	Cr O ₃	
Cd O	Pb O	Mn O ₃	

There is much to be done in accumulating facts on isomorphism, before it can be made as fully available and valuable in chemistry as it promises to be. It throws some light upon the manner in which bodies unite together; it brings together compounds that would otherwise not have been classed together; it has strengthened the atomic theory, and lent its aid in establishing combining weights. An interesting question arises, whether from the isomorphism of bodies, similarly combined, we can deduce their isomorphism, when separated, or in other combinations? From the same form of the alums, containing the sesquioxide of iron, aluminum, chrome, and manganese, we might then infer their similar forms, in a separate state; which agrees with observation for the first three. Tersulphurets of arsenic, antimony, and bismuth are right rhombic; the tritoxides of antimony and arsenic are isomorphous both in the right rhombic and regular systems. The sulphates of baryta, strontia, lime, and lead are right rhombic of one form, their carbonates right rhombic of another form. See DIMORPHISM.

ISOPYRE. *Min.* Compact. H. = 6—6.5. G. = 2.9—3. Velvet-black; vitreous; subtranslucent, opaque; brittle, with flat, conchoidal fracture, and light greenish gray streak; slightly magnetic. Fuses readily to a magneted globule, and leaves silica in mic. salt; scarcely attacked by acids, but readily after ignition with alkaline carbonates. Probable

ITACONIC ACID.

form. $2\text{FeO}(\text{CaO})$, $\text{SiO}_3 + \text{Al}_2\text{O}_3$, SiO_3 . From Cornwall, Eng.

ITACONIC ACID. *Chem.* Syn. Pyrocitric acid, Citric acid. $\text{C}_5\text{H}_2\text{O}_3$, HO. A solid product of the distillation of Aconitic and Citric acids. Its crystals are colorless, melt at 320° , and give CITRACONIC acid. Heated further it volatilizes. It is more soluble in boiling than in cold alcohol. Alcohol and ether both dissolve it. The itaconates of baryta and silica are soluble in water; the lead salt is insoluble.

ITTNERITE. See HAUYNE.

IVORY. The tusk of the male elephant. Is more brittle, compact, finer-grained, and susceptible of a higher polish than BONE, from which it differs only in proportional constitution.

For Vegetable ivory, see TAQUA NUT.

IVORY BLACK. A term usually applied to BONE BLACK, but more strictly belonging to the rich, black pigment prepared by calcining ivory scraps in closed vessels.

IXOLYTE. *Min.* A red, bituminous matter, allied to HARTITE, from Oberhart. It softens at 169° , and is still tenacious at 212° .

J.

JADE. See NEPHRITE.

JALAP. *Chem.* The root of the *Jalapá Ipomœa* contains

Resin	11.0
Acrid extractive	17.9
Gum and gummy extractive.....	33.2
Coloring matter.....	8.2
Saccharine matter	1.9
Albumen	3.9
Starch.....	6.0
Water.....	4.8
Salts of lime, potash, and magnesia .	8.5

Resin. Prepared by repeatedly digesting the sliced root in hot water, submitting it to pressure, and treating the residue in a water bath, three times consecutively, with alcohol of 0.898. The tinctures thus obtained, after being decolorized by animal charcoal, yield on distillation or evaporation, nearly colorless resin.

Jalap resin is frequently adulterated with guaiac resin, from which it is distinguishable by its insolubility in ether. Kayser has recommended as a test of its purity, the characteristic behavior of sulphuric acid, which in a few moments forms with it a beautiful carmine solution, soon passing to a brown shade.

Prop. When perfectly pure is insoluble in water and ether, but very soluble in alcohol, and consists of two resins,—

Alpha resin. Syn. Rhodeoretin, Jalapin. Formula $\text{C}_{42}\text{H}_{35}\text{O}_{20}$. Insoluble in water and ether, but soluble in alcohol. When boiled with potassa and ammonia, it is dissolved and transformed, by the absorption of 1 equiv. of water, into Rhodeoretic acid $= \text{C}_{42}\text{H}_{36}\text{O}_{21}$, which is soluble in alcohol and water, but not in ether; and gives, as does rhodeoretin, the characteristic carmine solution with oil of vitriol. Rhodeoretin, when decomposed by concen-

KAKODYL.

trated acids, gives grape sugar and Rhodeoretinol $= \text{C}_{42}\text{H}_{35}\text{O}_{20}$.

Beta resin. Obtained by distilling the ethereal extract of the resin. Has the strong, disagreeable smell of the root, and is probably the so-called jalappic acid. Soluble in ether, alcohol, and in aqueous solutions of potash or soda, from which latter it is separated, unaltered, by muriatic acid. Insoluble in water and the mineral acids. Left in contact with water for some months, acicular crystals are produced, and eventually form a smeary mass. *B. R.* 1846, p. 665.

JAMISONITE. *Min. Ger.* Bleischimmer. Cryst. Right Rhombic, with perfect basal cleavage; also columnar; $\text{H.} = 2 - 2.5$. $\text{G.} = 5.5 - 5.8$. Color and streak steel-gray; metallic; opaque, sectile. Decrepitates and fuses, giving off antimonial vapors; gives in an open tube volatile vapors of oxide of antimony, and fixed antimonite of lead. Decomposed by muriatic acid. Form. $2(\text{PbS} + \text{SbS}_3) + \text{PbS}$. From Cornwall.

JAPONIC ACID. See CATECHU.

JARGON. See ZIRCON.

JASPER. See QUARTZ.

JATROPHIC ACID. See CROTON OIL.

JEFFERSONITE. See AUGITE.

JELLY. Strictly speaking, the cooled solution of gelatin in boiling water. From their tremulous, jelly-like appearance and consistence, the cold solutions of starchy matters have also received this title.

JERVIN. See HELLEBORE.

JET. See COAL.

JOHANNITE. *Min.* Cryst. Oblique Rhombic; emerald-green; vitreous; transparent, opaque; streak yellowish green. Soluble in water with a bitter, styptic taste. Behaves to fluxes like oxide of uranium, and gives with soda a hepar. It is sulphate of oxide of uranium, probably basic, with water. From Joachimsthal, Bohemia.

JOHNITE. See CALAITE.

JUNCKERITE. See SPARRY IRON.

JUNIPER OIL. The volatile essence of the *Juniperus communis*. Consists of two oils identical in composition, C_8H_4 , but differing in spec. grav. and boiling points. They are separable by distillation; that which passes over first, has a spec. grav. 0.847, and its point of ebullition is 311 to 325 . The denser oil has a spec. grav. of 0.868, and does not boil below 536° . The pure oil polarizes to the left. Stenhouse found that after some months action of nitric acid, it forms a crystallized compound, $\text{C}_6\text{H}_5\text{O}$, which may be regarded as the hydrate of C_5H_4 . The light oil gives, with hydrochloric acid a liquid camphor $= \text{C}_{15}\text{H}_{12}$, ClH .

JURINITE. See BROOKITE.

K.

KAKODYL. *Chem.* A permanent compound radical, of strong affinities, acting in all its chemical relations as a metal. Form. $\text{C}_4\text{H}_6\text{As}$. (*Bunsen*.) It is an oily liquid, which at 21° crystallizes in square prisms; boils at 338° , and on exposure to air immediately inflames.

Prep. By heating the chloride of kakodyl with zinc, decomposition ensues, and the resultant chloride of zinc may be removed by water.

Protoxide of Kakodyl. Syn. Alkarsin, $C_4H_6AsO = KdO$. Prepared by slowly heating equal weights of acetate of potassa and of arsenious acid to redness in a glass retort, over a sand-bath. In the recipient, which must be surrounded with ice, will be found two liquids besides the metal, the heavier of which contains the oxide of kakodyl. To purify it, agitate the heavy liquid with water, to remove acetone or acetic acid, and rectify with caustic potassa in an atmosphere of carbonic acid gas. A final rectification over lime or baryta renders it anhydrous.

Prop. A colorless, ethereal liquid, boiling at 300° , and congealing into white, silky scales, at -10° ; miscible with alcohol and ether, sparingly soluble in water. Is a powerful poison, and emits garlicky, irritant fumes. It is a feeble base, but has a strong affinity for oxygen; and when acted upon by hydrogen acids in the manner of a metallic oxide, produces water and the compound of kakodyl with the radical of the acid, $KdO + HR = KdR + HO$.

The formula of the *dentoxide* of kakodyl is $C_4H_6AsO_2$.

Kakodylic acid. Syn. Alkargen. Formula $C_4H_6AsO_3 = KdO_3$. Results from the oxidation of the oxide of kakodyl, by the slow reaction of peroxide of mercury under water.

Prop. Colorless prisms, inodorous, and tasteless; deliquescent in moist air, insoluble in ether, but soluble in water, alcohol, and sulphuric acid, from which latter it crystallizes unaltered. Melts at 390° , partially decomposes, and at 195° solidifies again. Phosphorus acid, protochloride of tin, and metallic zinc deoxidize it. Forms salts soluble in water and alcohol.

Chloride of Kakodyl. $C_4H_6As, Cl = KdCl$. Prepared by mixing a dilute solution of bichloride of mercury with an alcoholic solution of oxide of kakodyl, recrystallizing the white precipitate thus formed from solution in boiling water. These crystals, when distilled with very strong hydrochloric acid, yields a clear ethereal liquid, which gives off offensive, irritant, very poisonous fumes; for these reasons great care is requisite in its preparation. Soluble in alcohol, but insoluble in ether and water, though it imparts its odor to the latter. On exposure to air it deposits crystals of oxychloride of kakodyl.

Sulphuret. C_4H_6AsS . A clear, disagreeably smelling liquid, heavier than, and insoluble in water.

Cyanide. C_4H_6As, Cy . Forms brilliant, fusible, and volatile crystals, of an offensive odor, and highly poisonous.

The admirable researches of Bunsen have established kakodyl as an organic radical, which can be isolated, and in connection with cyanogen lends great strength to the theory of compound radicals. If we examine its composition and the behaviour of its compounds, it may be regarded as a conjugate body, composed of $C_4H_2 + AsH_4$, which last corresponds to ammonium, NH_4 , with arsenic in place of

nitrogen. Hence the oxide of kakodyl resembles oxide of ammonium in combining with acids, and hence, too, its odor, reminding one of arseniuretted hydrogen, which corresponds to ammonia, so that it may either be $C_4H_2 + AsH_4O$, or $C_4H_2 + AsH_3, HO$.

KAKOPLATYL. A compound radical not yet isolated. A compound, according to Bunsen, is formed, when the alcoholic solutions of bichloride of platinum and chloride of kakodyl are mixed together. Its oxide is basic, and forms crystalline salts with acids.

KALIPHITE. *Min.* Fibrous. $H. = 1. G. = 2.8$. Brown, vitreous, opaque; fusible to a brown globule, giving the reaction of iron and manganese, and water in a tube. It is a hydrate of iron and manganese, with silicate of zinc, &c., but it appears to be a mixture.

KALIUM. The Latin name for potassium, and hence its symbol, K.

KAMMERERITE. *Min.* 6-sided prisms, with perfect basal cleavage into flexible foliæ. $H. = 2. G. = 2.76$. Violet-red; transparent, translucent; unctuous. Infusible, yields water, gives a green glass with borax and mic. salt, leaving silica in the latter; fuses with much soda to a slag. Its formula is nearly $2(MgO, SiO_3) + Al_2O_3 + 2HO$. From Perm, Siberia.

KAOLIN. Brogniart and Malaguti have made many examinations of kaolin, from which the formula of some is $3Al_2O_3, 4SiO_3 + 6HO$, of others $Al_2O_3, SiO_3 + 2HO$, which last they assume to be the true formula. See *Ann. d. Mines*, iv. Ser. II. 465, also in *Pogg. Ann.* lx. 89, and *Erd. Journ.* xxxi. 129. Wolf's analysis gives the former formula for one kaolin, and for another $2(Al_2O_3, SiO_3) + 3HO$. See *Erd. Journ.* xxiv. 221. See also several analyses under CLAY.

It is generally believed to be derived from the decomposition of feldspar, by the loss of the larger portion of silicate of potassa, of which it retains a small amount. It is generally free from iron, and this constitutes its value in the manufacture of fine earthenware and porcelain. It occurs, among other localities, in the N. E. part of Delaware; in York and Chester Cos., Penn.

KARPOLITE. *Min.* $H. = 5. G. = 2.935$. Columnar, radiated; yellow; silky, glistening; opaque; very brittle. It yields a little fluoric acid in a tube; on charcoal it swells, fuses to a brownish glass, and gives a manganese reaction with the fluxes; insoluble in acids. Form. $3MnO(FeO), SiO_3 + 3(Al_2O_3, SiO_3) + 6HO$. *Local.* Schlackenwald, Bohemia.

KARPHOSIDERITE. *Min.* $H. = 4. G. = 2.5$. Yellow, resinous, greasy. Fusible on coal to a black, magnetic globule. It is probably a hydraous, basic phosphate of peroxide of iron.

KARSTENITE. See ANHYDRITE.

KEILHAUTE. *Min.* Yttrotitanite. Crystalline, lamellar. $H. = 6.5. G. = 3.69$. Dark brown, with a reddish streak; vitreous on the cleavage surface; otherwise resinous; translucent on the edges; conchoidal fracture. Fuses with effervescence to a shining black slag; gives iron reaction in borax, and be-

KELP.

comes blood-red in the reducing flame; gives a skeleton of silica in mic. salt; with soda it shows manganese. Form. 3 (3 CaO, 2 SiO₃) + R₂O₃, SiO₃ + YO, 3 ZiO₂. Arendal, Sweden.

KELP. See SODA.

KERASITE. See MENDIFFITE.

KERMES. An insect (*Coccus ilicis*) found in Asia and the southern part of Europe. From their similarity to seeds they were formerly called *grains of kermes*. Like cochineal, they give a scarlet and crimson dye, but of less brilliancy and more durability.

KERMES' MINERAL. See ANTIMONY.

KEROLITE. *Min.* Hydrosilicate. H. = 2. G. = 2—2.2. White, green; reniform masses, with lamellar structure; vitreous, resinous; transparent, translucent; greasy; conchoidal fracture. In a tube it becomes black, and gives off water; infusible. Form. 2 (3 MgO, 2 SiO₂ + 2 HO) + MgHO. It occurs at Frankenstein, Silesia; Hoboken, N. Jersey, &c.

KIDNEYS. The animal organs in which urine is secreted. The separation of the water is due to the peculiar internal structure of the organ, and the UREA, URIC ACID, and salts, partially to the chemical constitution of the renal cells, and the appropriately directed co-operation of the nerves of these organs, and partially to the composition of the blood itself, which differs from that which supplies the liver. Whether, however, its saline components are, so to speak, mechanically carried away in the water which holds them in solution, and which permeates the textures of the kidneys, or whether their separation is a true secretion of the renal cells, due to their organized development, is yet unknown.

KILBRICKENITE. See GEOKRONITE.

KILLINITE. See SPODUMEN.

KINIC ACID. See QUINIC ACID.

KINO. The Indian name of an astringent, extractive matter, coming in two varieties; one from Africa, and the other from the East and West Indies. They are the products of different plants. Both species consist mostly of tannin, extractive, red gum, insoluble matter, and, according to Buchner, *Catechin*. (See CATECHU.) To this latter ingredient is due the power of giving a green color to the salts of iron. The African kind, according to Stenhouse, is converted wholly into oxalic acid by digestion with nitric acid. Kino, from the *Coccoloba uvifera*, when treated consecutively by cold water, sulphuric acid, hot water, and barytes, yields *Kinoic* or *Cocotannic* acid, a crimson mass, soluble in alcohol and water, insoluble in ether, and forming salts of which little is yet known. It does not precipitate the solution of tartar emetic.

The kino described in Pereira's work is from the *Pterocarpus rinaceus*.

KINOIC ACID. See KINO.

KINOVIC ACID. Exists in the *Cinchona nova*. Brilliant white, soluble in alcohol and ether, but very slightly in water. With the bases it forms kinovates. It has been but little studied.

KIRWANITE. *Min.* H. = 2. G. = 2.941. Dark olive-green, opaque, radiated fibrous.

KROKIDOLITE.

Form. 3 [2 CaO (FeO), SiO₃] + Al₂O₃, SiO₃ + 2 HO. From Basalt, on N. E. coast of Ireland.

KLINOCLEASE. Damour and Rammelsberg give for the formula of apaphanite (klinoclase), 3 CuO, AsO₃ + 3 (CuO, HO). See APAPHANITE.

KNABELITE. *Min.* Massive and hard. G. = 3.71. Gray, red, brown, green; glistening; opaque; brittle with subconchoidal fracture. Unalterable by heat; gives the reactions of iron and manganese. Form. 3 FeO, SiO₃ + 3 MnO, SiO₃, or 3 RO, SiO₃.

KOBELLITE. *Min.* G. = 6.29—6.32. Resembles gray antimony, but has a higher lustre. Behaves like the same mineral, but leaves a globule of lead. Form. 3 FeS, 2 SbS₃ + 3 PbS, BiS₃.

KOLLYRITE. *Min.* H. = 2—3. White; vitreous, translucent, opaque; adheres to the tongue. Yields water in a tube, and is infusible. Form. 3 Al₂O₃, SiO₃ + 15 HO.

KOMENIC ACID. See MECONIC ACID.

KONIGIN. See BROCHANTITE.

KOREITE. See AGALMATOLITE.

KOUMISS. Syn. Kumiss. A rectified brandy distilled from sour mare's milk. Its preparation depends on the fermentation of lactin or milk sugar.

KOUPHOLITE. See PREHNITE.

KRAHLITE. Obsidian, from Iceland.

KRAMERIC ACID. See CRAMERIA.

KREATIN. *Chem.* Syn. Creatin. A neutral substance, C₈N₃H₁₁O₆, discovered by Chevreul in the juice of flesh, the proportion varying in different animals from 0.607 to 3.21 per 1000. It has also been found in the normal urine of man, by Heintz. For modes of preparation see Liebig's *Turner*, 8th ed. p. 1218, and *Chem. Gaz.* v. 157.

Prop. Forms brilliant, transparent crystals, which become opaque at 212°, by loss of water of crystallization. Is sparingly soluble in alcohol, readily so in water, imparting a bitter taste. Strong mineral acids transform it into *Kreatinin*, and long continued boiling with concentrated barytic water changes it into *Sarcosin* and urea.

Kreatinin. C₈N₃H₇O₂. Formed as above, and exists also naturally in the juice of flesh and in urine. (Pettenkofer and Liebig.) It is a strong base, exactly analogous to ammonia in its chemical characters. Is soluble in water and alcohol. The hydrochlorate of kreatinin forms colorless prisms, soluble in water and alcohol. The sulphate forms a white, saline mass, soluble in hot alcohol.

Sarcosin. C₆NH₇O₄. Crystallizes in right rhombs which are colorless, insoluble in ether, and difficultly so in alcohol, but very soluble in water. Sublimes unaltered at 212°, and forms salts with the acids. Is isomeric with lactamide and urethane, but is distinguished from them by its basic character and by other properties.

KRISUVIGITE. See BROCHANTITE.

KROKIDOLITE. *Min. Gr.* Blau-eisenstein. Fibrous and massive. H. = 4. G. = 3.2—3.265. Lavender-blue or leek-green; opaque; fibres somewhat elastic. Fusible to a brown

slag, giving iron and silica in borax and mic. salt. $3 \text{ NaO} (3 \text{ MgO}), 4 \text{ SiO}_3 + 3 (3 \text{ FeO}, 2 \text{ SiO}_3 + \text{XHO})$.

KRYPTOLITE. *Min.* Hexagonal prisms; wine-yellow, transparent. $G. = 4.6$. Soluble in oil of vitriol. Probable form. $3 \text{ CeO}, \text{PO}_5$. From a reddish apatite from Arendal, Sweden. *Wöhler*.

KUPAPHRITE. See **COPPER FROTH**.

KUTEERA. A tasteless, inodorous gum, mostly transparent; the product of the *Ser-tulio urens*, a tree growing in Hindostan. In cold water it forms a pulp or jelly-like traga-canth, but when pulverized and well boiled therewith, is completely dissolved. It is used by the calico printers, and in India as an ingredient of certain kinds of varnish.

KYANITE. *Min.* Cyanite, Disthen, Fibrolite, Rhätizite. Cryst. Triclinic; usually in long, flat prisms. $H. = 5 - 7$, depending on the surface; $G. = 3.56 - 3.68$. Color blue, white, greenish black; lustre pearly on cleavage surface, otherwise vitreous; transparent, subtranslucent; brittle, with uneven fracture.

Chem. Rel. Unaltered by ignition, becoming white at a high heat; slowly soluble in borax; leaves a skeleton of silica in mic. salt; partially fusible, with a little soda, to a semi-transparent mass, rose-red in exterior, colorless in interior flame, infusible with more soda; with cobalt becomes blue. Decomposed by ignition with potassa. Formula $2 \text{ Al}_2\text{O}_3, \text{SiO}_3 (?)$.

KYANOLE. See **INDIGO**.

KYROSITE. Is probably Radiated **IRON PYRITES**.

L.

LABDANUM. A brown, odorant resin, from the *Cistus creticus*.

LABORATORY. The place or locality in which chemical operations are performed. The experimental laboratory differs from that for manufacturing purposes, in requiring less extent of room and more delicate apparatus. For particulars as to a proper arrangement and the modes of performing the mechanical operations, see Faraday's "*Chemical Manipulations*," and Morfit's "*Chemical and Pharmaceutical Manipulations*."

LABRADORITE. *Min.* Labrador feldspar. Anhydrous scolezite, glaukolite, silicite (?). Cryst. Triclinic, with two distinct cleavages. $H. = 6$. $G. = 2.69 - 2.76$. Gray, brown, green; in different positions it generally shows beautiful colors, blue and green predominating; lustre vitreous; translucent, subtranslucent; in general features resembles feldspar. In its behavior it resembles feldspar, but fuses rather more readily; partially decomposed by acids. Form. $\text{CaO}, \text{SiO}_3 + \text{Al}_2\text{O}_3, \text{SiO}_3$, in which the CaO contains usually soda and magnesia. *Local.* Coast of Labrador; Essex Co., N. Y., and other counties, in boulders. See **FELDSPATHIC MINERALS**.

LAC. *Tech. Ger.* Gummilack. A resinous substance derived from the twigs of *ficus* and other plants, when punctured by a coccus insect. The twigs broken off with the adhering resin constitute stick-lac; the resin broken off

from these is seed-lac; and when melted by warmth in a canvas bag, and pressed out so as to spread into thin plates, it constitutes shell-lac. According to Hatchett, stick-lac contains 68 pr. ct. resin and 10 pr. ct. color; and shell-lac 90 resin and 0.5 color; from which it appears that the greater part of the color has been removed.

John's analysis of seed-lac gives—

Resin, part insoluble in ether.....	66.67
Lactin (Lackstoff).....	16.67
Coloring matter.....	3.75
Extractive.....	2.92
Laccic acid.....	0.63
Coats of insects.....	2.08
Waxy fat.....	1.67
Salts.....	1.04
Sand and loss.....	4.57

100.00

Resin and the coloring matter are the two principal ingredients of lac. The resin is soluble in strong alcohol, aided by heat. It has, like most resins, a strong affinity for bases, but it also dissolves in dilute muriatic and acetic acids. Boiled with carbonate of potassa or soda, or covered with ammonia for 12 hours, it does not dissolve in the fixed alkaline solution, but readily in hot water. It also dissolves in borax solution. The solution in ammonia may be used as a varnish, where the articles coated with it are not exposed more than an hour or two to water. If the dark alkaline solutions be treated with chlorine until the solution is saturated, the resin, in separating from the liquid, becomes white. It keeps white on drying, and dissolves in alcohol with a light yellow color. Unverdorben's analysis gives several resins, alpha, beta, &c.

α Resin. The lac contains about 50 pr. ct. It is soluble in 67 pr. ct. alcohol, and in ether; brown, fusible, giving a violet solution with potassa, precipitable by salts of lead and copper.

β Resin. (0.7 pr. ct.) Brown, hard, soluble in alcohol, not in ether; precipitates acetate of copper, and decomposes carbonate of magnesia. Unverdorben states that these two resins, in solution in potassa, partly change into oleic and margaric acids.

γ Resin separates from its alcoholic or ethereal solution in crystalline needles. It may be obtained by boiling a solution of lac in alcohol, with carbonate of magnesia, when its salt with magnesia separates. This salt is insoluble in potassa.

δ Resin is soluble in alcohol and ether, but not in petroleum; it is soft, and fuses at 212° .

ε Resin is soluble in alcohol, ether, volatile oils, and potassa, by the latter of which it is decomposed. This resinous body and the *lack-stoff* resemble each other, and are changed by alkalies into true resin.

The whole resin is generally employed in the state of shell-lac, the red coloring principle having been previously separated from it. Shell-lac constitutes the basis of sealing wax and of many varnishes.

Sealing wax. The lac being brittle, is ren-

dered tougher by fusing it with Venice or other terpentine. A good composition for red sealing wax is 4 pts. lac, 1 or $1\frac{1}{2}$ Venice terpentine, and 3 pts. vermilion; the lac is fused by a slow heat, the terpentine stirred in, and finally the vermilion. The mass is then rolled on a warm slab into rounded sticks, or may be pressed in moulds. Black is made by fine bone or lamp-black; yellow by chromate of lead; blue and green, cobalt glass alone or with chrome yellow. A small proportion of balsam of Peru imparts an agreeable odor to the burning wax. Several colored waxes mixed in their semi-fluid state form a marbled wax. To give light tones of color, a decolorized lac is required, to which is added a white ground, together with the desired color. An inferior quality of wax is made by adding rosin and bees-wax to the lac, and coloring with brick-dust, red-lead, &c. Such a wax has an inferior color (if red), is more brittle, fuses and drops rapidly in a flame. See VARNISH.

LACCIC ACID. See LAC.

LACQUER. An alcoholic solution of shellac, tinted with the coloring matter of saffron or annatto, and used as a golden varnish for wooden and metallic vessels.

LACTIC ACID. *Chem. Syn.* Nancéic Acid. (*Iraconnot.*) Formula $C_6H_6O_6$. Discovered by Scheele. Exists in urine, milk, gastric juice, the yellow of egg, and in almost all the animal fluids. It is generated during the *lactic fermentation* in the juices of beet-root, turnips, carrots, sour-kraut, rice-water, nux vomica, oak bark; in the solution of sugar when casein is present, and in the putrefaction of certain animal matters.

Prep. 6 lbs. of cane sugar and $\frac{1}{2}$ oz. of tartaric acid are dissolved in 26 lbs. of boiling water, and set aside for some days; 8 oz. of old, stinking cheese, well diffused in 8 lbs. of curdled acid milk, from which the cream has been removed, are added to the above mixture, along with 3 lbs. of finely-powdered chalk, the whole located in a warm place, so that the temperature of the liquid is from 86° to 95° . It is well stirred every day for several times; in the course of 8 to 10 days the entire mass solidifies to a stiff paste of lactate of lime; 20 lbs. of boiling water and $\frac{1}{2}$ oz. of caustic lime are added to this paste, boiled for half an hour, and filtered through a linen bag. The liquid is evaporated to the consistency of a syrup, set aside for four days, in which time the lactate of lime has separated in a granular, crystalline form; it is expressed, then agitated with one-tenth its weight of cold water, again submitted to pressure, and this operation repeated two or three times.

The lactate of lime, after being expressed as well as possible, is dissolved in twice its weight of boiling water; and for every pound of expressed lactate of lime, $3\frac{1}{2}$ oz. of sulphuric acid, previously diluted with its weight of water, added to the solution. The hot liquid is immediately filtered through a conical bag, from the gypsum, and boiled with $1\frac{1}{2}$ lbs. of carbonate of zinc for every 1 lb. of sulphuric acid used for a quarter of an hour; if boiled longer, a very insoluble basic salt is formed. The solution, filtered boiling hot, soon deposits

perfectly colorless lactate of zinc in crystalline crusts, which may be obtained perfectly free from sulphuric acid by rinsing with cold water. The mother-ley is again boiled with any of the salt which may have remained on the strainer, or concentrated by evaporation. It yields, nearly to the last drop, perfectly white zinc salt.

To separate the lactic acid from this salt, dissolve it in $7\frac{1}{2}$ pts. of boiling water, pass a current of sulphuretted hydrogen into the hot liquid until it has become cold, and no further separation of sulphuret of zinc is perceptible. The liquid filtered from the sulphuret of zinc is boiled, to expel the excess of sulphuretted hydrogen, and then evaporated in a water-bath to the consistence of a syrup. 8 pts. of lactate of zinc yield in this manner 5 pts. of perfectly pure, syrupy lactic acid. *Chem. Gaz.* v. 206.

Prop. A colorless, syrupy liquid, of spec. grav. 1.215 at 68° . Soluble in water, alcohol, and ether. Is a solvent of oxalate of lime (*Lehman*), and of phosphate of lime, and coagulates albumen. It dissolves in cold milk without change until heat is applied, when coagulation ensues. It forms salts with the acids, and is said to be bibasic. (*Maddrell and Englehart, Chem. Gaz.* v. 484, vi. 298.)

Lactic acid, when heated at 212° , becomes anhydrous, $C_6H_5O_5$. Solid and almost insoluble in water, but gradually resumes its original properties by exposure to moist air. The compound of this anhydrous acid with ammonia, is termed by Laurent a lactainminate. By increasing the heat to 480° , it sublimes into crystalline *lactide*. The latter is accompanied with *lactone*, $C_{10}H_8O_5$, HO, a light, colorless, aromatic liquid, soluble in water, and becoming yellow on exposure.

Lactide. $C_6H_8O_4$. Forms white, rhombic tables of acid taste, soluble in alcohol and water. Its ammoniacal compound, *lactamide*, has the composition $C_6H_4N_4 + NH_3$.

Salts. All the lactates part with water of crystallization *in vacuo*. The lactates of fixed bases are changed at a red heat into carbonates.

Lactate of Silver. $AgO, C_6H_5O_5$. Silky needles, soluble in hot water and alcohol, and precipitable from the solution by ether.

Lactate of Protoxide of Iron. $FeO, C_6H_5O_5 + 3HO$. Yellow needles, sparingly soluble in cold, but soluble in boiling water and in alcohol. The per-salt is not crystallizable.

Lactate of Zinc. $ZnO, C_6H_5O_5 + 3HO$. Soluble in cold, more so in hot water, but almost insoluble in alcohol. Crystallizes in prisms. Precipitated from its aqueous solution by water, as a basic, crystallizable salt.

Lactate of Lime. $C_6H_5O_5, CaO, 6HO$. Exists in nux vomica, and is generally obtained as a chalky, crystalline mass, soluble in water and boiling alcohol, and crystallizes from the latter on cooling. Ether does not dissolve it. Like the zinc salt, it falls in a crystalline state when a solution of acetate is added to lactate of lime dissolved in four parts of water. *Archiv. der Pharm.* xlviii. 258.

Lactates of ammonia, potassa, and soda are deliquescent and uncrystallizable.

Lactic Ether, according to Lepage, is a transparent, colorless liquid, of spec. grav. 0.866 at 48° F. It boils at 170.6°, is soluble in water, alcohol, and ether, and is decomposed by the alkalis.

LACTIN. See SUGAR OF MILK.

LACTUCARIUM. Syn. Thrydace, Lettuce Opium. The inspissated, milky juice of the *lactuca sativa*, *l. virosa*, *l. scariola*, *l. altissima*. Aubergier pronounces a difference between that prepared by extraction and that obtained by incision. The lactucarium of the *L. altissima*, which yields it most abundantly, contains mannite, asparamide, an indifferent and a negative resin, wax, pectin, albumen, oxalate, malate, nitrate and sulphate of potassa, and chloride of potassium, and a crystalline substance which is colored red by alkalis and green by the salts of sesquioxide of iron. By heat or the action of alkalis, it is easily transformed into alinic acid. Moreover, this lactucarium contains a neutral, non-volatile, and probably active principle, insoluble in cold water and ether, soluble in alcohol, and deposits, on cooling from its hot aqueous solution, in pearly scales. The bitterness of the solution, which alkalis destroy, is not restored by acids.

Composition. Schlessinger found in that from the *L. virosa*; wax, resin, extract and gum, albumen, lime salt, fibre, water.

Waltz obtained a pulverizable fat, of the odor of lettuce, and soluble in ether; another fat of the odor of lactucarium, and difficultly soluble in ether; a reddish yellow and greenish yellow resin; a body resembling humic acid; a similar basic body, and oxalic acid. The lactucarium, from the *L. sativa*, gave to Aubergier mannite, asparagin, and pectin, in addition to the components (except caoutchouc) found by other chemists. Besides lactucin it contains, says Pagenstecher, a soft, crystalline, bitter, neutral substance, white when pure, soluble in water and alcohol, decomposable by the sulphuric and nitric acids, and differing from the lactucin by its color and insolubility in ether. The acid substance which exists in Thridace, and called *lactucic acid* by Pfaff, is, say Köhuke and Waltz, the oxalic. The acid properties of the fresh plant are due to the presence of citric, malic, and succinic acids, but not oxalic.

Lactucin. Prepared pure by treating lactucarium with alcohol containing $\frac{1}{10}$ th of acetic acid, diluting the solution with water, precipitating by acetate of lead, filtering, passing sulphuretted hydrogen, evaporating between 120° and 140°, extract with alcohol, distilling, and repeatedly treating the residue with ether, which on evaporation leaves the lactucin.

Prop. Yellow, neutral, crystallizable in confused needles, inodorous, fusible but with decomposition, soluble in water, alcohol, acetic acid and ether. Dilute hydrochloric and nitric acids are without action, but concentrated sulphuric acid colors it brown. Strong nitric acid transforms it into a brown, resinous mass.

Lenoir (Liebig's *Ann.* 1846), in some late investigations of the lactucarium from the *L. virosa*, attempts to show that Waltz and Auber-

ger's active organic principle (lactucin), is a peculiar, indifferent body, hitherto unknown in its pure state. He calls it *Lactuone*, and thus describes it:—

Prop. Lactucone, $C_{40}H_{32}O_3$, separates in warty aggregations from a filtered, hot alcoholic solution of lactucarium. By repeated crystallization from alcohol, it is freed of coloring matter and bitter substance.

Prop. Crystallizes in minute, colorless prisms, in radiate or warty masses, but when impure separates in amorphous vermicoid masses. Tasteless, inodorous, nearly insoluble in water, readily soluble in alcohol, ether, essential and fatty oils, and naphtha, from which latter it best crystallizes. Fuses without decomposition between 302° and 392°. Is not volatile except in a current of carbonic acid gas, and then sublimates mostly undecomposed, emitting at the same time the odor of melted caoutchouc; is apparently without action upon the organism, and is a highly indifferent body, neither chlorine nor potassa having acted upon its aqueous or alcoholic solution.

Though similar in properties to belutin, it differs essentially in several particulars, though in composition it varies only by one equiv. of hydrogen.

Ludwig (*Archiv. der Pharm.* i. pp. 1 and 129), who more recently analyzed lactucarium, gives as its constituents,—

Lactucerin or lactucone ...	42.64	} 48.63 of matter insoluble in water.
Fusible waxy matter	3.99	
Fibre and a substance insoluble in water, alcohol, and ether, but which swells in ammonia	2.00	
Albumen (grayish)	6.98	
Extract soluble in alcohol and water, (containing lactucic acid and the lactucin of Aubergier,)	27.68	} 51.37 pr. ct. of matter soluble in water.
Extract, insoluble in alcohol of 0.830	14.96	
Lactucerin held in solution in water, by the other substances	1.75	

LAKES. The precipitated coloring matters of vegetable solutions, formed by the addition of alum, tin, or iron salts. They are soluble compounds of the coloring matter, and the base of the salt used. See COCHINEAL, INDIGO, and Madder.

LAMP BLACK. *Tech.* The condensed carbon arising from the smoke of highly carbonaceous bodies, undergoing combustion with imperfect access of air. Turpentine, pitch, &c., are usually thus burned, and the smoky products of combustion passed into chambers in which the black condenses. It is a very pure carbon, and may be further purified by digestion with alcohol, potassa, and water.

LAMPIC ACID. See ACETULE.

LANARKITE. See DIOXYLITE.

LANTHANUM. *Chem. Sym. Ln.* Eq. 40.8 (?). A metal originally found by Mosander in cerite. It exists also in gadolinite, orthite, allanite, &c., accompanied by cerium and didymium, and derives its name from *λανθάνειν*,

to lie hid, from its having been concealed in ceritic minerals. Hermann obtained it from cerite, by dissolving the finely powdered mineral in boiling hydrochloric acid, separating the silica by the usual method, neutralizing the solution with ammonia, and precipitating the peroxide of iron with succinate of ammonia. An excess of ammonia is then added to the filtered liquid, and the bulky precipitate of protoxide of cerium and oxide of lanthanum contaminated with lime, magnesia, alumina, and oxide of manganese, is collected in a filter. This precipitate is dissolved in nitric acid, evaporated to dryness, and the salt ignited, then finely powdered and digested with nitric acid (diluted with 50 pts. water to one of acid), and filtered. Ammonia being added in such excess as not to produce any permanent precipitate, the solution is then treated with phosphoric acid, and warmed.

A white, pulverulent precipitate of phosphate of lanthanum is formed, while alumina, lime, magnesia, and oxide of manganese, in combination with phosphoric acid, remain dissolved in the acid liquid, and may be separated on the addition of ammonia as phosphates. The phosphate of lanthanum is now free from any mixture of earth, but it still contains oxide of cerium. To separate it, the dried phosphate of lanthanum is mixed with double its weight of carbonate of soda, and heated to redness. On digesting the ignited mass with water, ceriferous oxide of lanthanum remains undissolved. It is dissolved in nitric acid diluted 100 times, when the oxide of cerium remains undissolved. The filtered solution is evaporated to dryness, the nitrate ignited, the oxide again dissolved in dilute nitric acid, and these operations repeated as long as oxide of cerium remains behind on dissolving the oxide of lanthanum. In this manner an oxide of lanthanum is obtained, in which not a trace of cerium can be detected by reagents. This oxide of lanthanum is dissolved in sulphuric acid and crystallized, when a bright rose-red, prismatic salt, in radiant groups, is formed of perfectly pure sulphate of lanthanum.

As the salts of lanthanum are colorless, this rose tint must be owing to the presence of traces of didymium. The metal is reduced from the chloride by heating with potassium. When washed with alcohol, it appears as a powder of metallic lustre, and soft to the touch. In contact with water, or when heated, it becomes oxidized. *Chem. Gaz.* ii. 91.

Oxide. Formula LaO . Obtained by ignition of the nitrate or calcination of the carbonate. Is a dirty white powder, forming salts with the acids. When reprecipitated from a salt by caustic alkali, it becomes hydrated, and on exposure absorbs carbonic acid, at the same time changing in color to snowy whiteness.

Chloride. Amethystine crystals, which deliquesce on exposure. It forms also a basic chloride as a white powder, difficultly soluble in water.

Sulphuret. A yellow powder which, in contact with water, disengages sulphuretted hydrogen, and becomes hydrated oxide of lanthanum.

Sulphate. $\text{LaO}, \text{SO}_3, 3 \text{HO}$. Colorless, circular lanthanum crystals, sparingly soluble in water, and which lose water at a faint red heat, and become opaque without melting. A greater heat reduces it to $3 \text{LaO}, \text{SO}_3$.

Nitrate. Crystallizes in colorless prisms, deliquescent and soluble in alcohol. Loses water by heat, becomes subnitrate, and ultimately pure oxide.

Carbonates. There are two carbonates, one with five eqivs. of acid to six of base, and crystalline; the other neutral, and chalk-like in appearance.

LAPIS LAZULI. See HAUYNE.

LARDITE. See AGALMATOLITE.

LACIONITE. See WAVELLITE.

LATENT HEAT. See HEAT.

LATROBITE. See AMPHODELITE.

LAUREL WATER. Prepared by distilling water over the leaves of the cherry laurel (*Cerasus laurocerasus*), and thus charging it with the essential oil of the plant.

LAURUS NOBILIS. Syn. Sweet Bay. Bonastre found in the berries,—

Volatile oil	0.8
Laurin	1.0
Fixed oil	12.8
Wax (stearin ?)	7.1
Resin	1.6
Uncrystallizable sugar	0.4
Gummy extractive	17.2
Bassorin	6.4
Starch	25.9
Woody fibre	18.8
Soluble albumen	trace
Acid	0.1
Water	6.4
Carbonates of potassa and lime, and phosphate of lime	1.5

Volatile Oil. Obtained by distillation from the leaves and berries. Viscid and dirty white, soluble in alcohol and ether, and congeals above 0° . Spec. grav. 0.914, and when rectified yields two isomeric oils, one of spec. grav. 0.857, and another of 0.885, and a brown, resinous residuum, containing 73 pr. ct. of carbon. Recently distilled oil has the formula $\text{C}_{20}\text{H}_{16}\text{O}$. Brandes.

Laurin. According to Mason does not exist in this plant, it being substituted by a principle termed by that chemist *laurostearin*. Ricord Madiana, however, found it in *La Persica*.

Lauro-stearine ($\text{C}_{27}\text{H}_{25}\text{O}_4$) drops from a cooling alcoholic decoction of the berries in brilliant, white, crystalline grains. Soluble in ether and hot alcohol, fusible at 110° to 115° . By saponification it yields *laurostearic acid* and glycerin.

Laurostearic Acid. $\text{C}_{24}\text{H}_{23}\text{O}_3 + \text{HO}$. Fuses between 108° and 110° ; is insoluble in water, but drops from its alcoholic or ethereal solution in amorphous particles. With the bases it forms salts.

LAUMONITE. *Min.* Efflorescing Zeolite. Cryst. Oblique Rhombic. $\text{H.} = 3.5 - 4$. $\text{G.} = 2.3$. White; vitreous; transparent, becomes opaque by exposure; brittle. Behaves like the zeolites, frothing and fusing to a porous mass; perfectly decomposed by muriatic acid, the silica gelatinizing. Form. 3CaO ,

$2\text{SiO}_3 + 4(\text{Al}_2\text{O}_3, 2\text{SiO}_3) + 18\text{HO}$, in which it bears analogy to phillipsite and harmotome.

Local. Faroe Islands; Disco, Greenland; Fassathal, St. Gothard; Peter's-point, Nova Scotia; Phippsburg, Maine; Charlestown, Mass.; Bradleysville, Southbury, Conn.; Bergen Hill, opposite N. Y.; Columbia Bridge, near Philadelphia, Penn., in well defined crystals.

LAVA. *Geol.* Cellular rocks in the vicinity of volcanoes, from which they have issued. They are fused masses, composed of mixtures of various minerals, such as labradorite, augite, &c. One part is decomposed by muriatic acid, its silex being removed by caustic potassa, and another part requires ignition with carbonate of soda for analysis. Volcanic ashes are of a similar nature.

LAVENDULAN. *Min.* A blue, translucent, amorphous arseniate of cobalt, nickel, and copper, with water, from Annaberg, Saxony. $H. = 2.5 - 3.$ $G. = 3.014.$ It fuses easily, and colors the outer flame blue; it readily yields water, arsenic, and cobalt to the tests.

LAZULITE. *Min.* Azurite, Azurestone, Blue Spar, Voraulite. Cryst. Right Rhombic; also granular, coherent. $H. = 5 - 6.$ $G. = 3.057.$ Various shades of azure-blue, with a white streak; vitreous; subtranslucent, opaque; brittle, with uneven fracture.

It yields water in a closed tube, and becomes white; it swells on coal, and puffs without fusing; gives a fine blue with cobalt solution; almost wholly soluble in acid after ignition. $\text{Frm. } 2(3\text{RO}, \text{PO}_5) + 4\text{Al}_2\text{O}_3, 3\text{PO}_5 + 6\text{HO}$, in which the first member is contained in VIVIANITE, and the second in WAVELLITE. *Rammelsberg.*

LEAD. *Min.* Cryst. Regular. Found native in minute quantity in galena, in the lava of Madeira, and in an argillaceous rock at Carthagera.

LEAD. *Chem. Lat.* Plumbum, Saturnus. *Ger.* Blei. *Fr.* Plomb. Known from the earliest times, and even among uncivilized nations, from the ease with which it may be obtained from its ores. Lead occurs almost always in the state of sulphuret, or galena, which when pure contains 86.66 pr. ct. metal. A small quantity of carbonate of lead is often mixed with galena, and has some influence on its metallurgic treatment; it contains 83.58 pr. ct. metal.

METALLURGY OF LEAD.

Although lead may be readily run out from the ores by a moderate heat, and with crude furnace arrangements, yet to obtain as much lead as possible at the least cost, has given rise to a variety of furnaces and processes, none of which are to be regarded as perfected. Galena is reduced in low blast furnaces or in reverberatories. It is first completely roasted, and then reduced; or it is partially roasted and reduced; or it is reduced by metallic and oxide of iron with or without roasting. Low blast furnaces are less generally employed for reducing galena, as experience has shown the loss of lead to be too great. Thus an ore containing about 80 pr. ct. may yield from 40

to 50 pts. of metal. But such furnaces are convenient for smelting carbonate of lead, litharge, or rich slags.

1. *Roasting and Reduction in a Reverberatory* is employed in England and at several places on the Continent, of which that at Bleiberg, Carinthia, seems to be well conducted. The furnace is a reverberatory about 10 ft. long by 6 broad, and has a hearth sloping towards the chimney-flue. *a. Roasting.* The stamped ore, concentrated by washing, is spread evenly over the hearth, the heat raised to a low redness (a great part of the heat being due to the burning off of the sulphur in the galena), and rabbled every half hour during 3 hours, which completes the 1st operation or roasting. During this operation the oxygen of the air burns off a portion of sulphur as sulphurous acid, some of which escapes; but the metal itself oxidizing at the same time, produces the formation of sulphuric acid, and consequently of sulphate of lead. The mixture therefore consists of unaltered galena, oxide, and sulphate of lead.

b. Sweating. The temperature of the furnace is now gradually raised, when lead begins to flow out at the lower end into an iron pot. After ceasing to flow, the dross and cinder are raked together into a heap, and a fresh charge passed through the same processes. The reaction of galena upon oxide is to form sulphurous acid, and metallic lead, and a portion of subsulphuret; the reaction of oxide on sulphate is to form a subsulphate.

c. Reduction. The rich cinder and dross are spread out upon the hearth, and fine coal thrown over it, mixed with the ore, and the mixture pushed to a heap, and a higher heat given, whereby a new portion of lead flows out. The metal arises partly from the same reactions as the preceding, and partly from the reduction of the subsulphate to a subsulphuret, which is resolved into metal and sulphuret. It is again spread out, roasted, covered with coal and a portion of lime, again heated, and thus several times roasted and reduced, until the cinder is too poor to yield more metal. By the addition of lime, a portion of it takes up sulphur to form sulphuret of calcium, and frees some lead; another portion takes up sulphuric acid, setting oxide of lead free, which is reduced to metal by the coal; and another portion uniting with the silica and earthy matters of the ore, exclude oxide of lead from the combination. The richer the ores are, the less is the loss by this smelting operation, being often as low as 2 pr. ct. metal.

This furnace has been latterly improved by having two hearths, one above the other, on the upper of which the roasting and partly the sweating is conducted, while on the lower reduction is effected.

The reverberatories used in the reduction of lead ores vary but little from the above, some having the hearth of a basin-shape, and allowing the melted lead to collect in the basin. The operation is divided into several stages, in each of which the heat is increased successively; but lime is used towards the close to *dry* up the slags. The amount of roasting depends on the quantity of carbonate of lead

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in the ore; for the more oxide there is present, the less need for roasting. Where there is a sufficient amount of fluor-spar, this is employed, with a portion of lime, in the latter stages of the operation, whereby a very liquid and poor slag is produced, which is run off, together with richer slags, which are dried up with lime. The rich slags from these operations are reduced in a low blast furnace.

2. *Reduction of Roasted ore* is performed in low blast furnaces, as the Scotch hearth, 2—3 ft. high; the slag hearth, 3—4 ft. high, and similar to the Scotch hearth; the Krummofen used in Germany for reducing the ore direct, 4—5 ft. high; and the Halbhohofen, 6—12 ft. high. These furnaces are better adapted to smelting poorer ores than the preceding, as well as for reducing the native carbonate of lead. The sulphuretted ore is roasted in heaps, or better in reverberatories, and then reduced in the blast furnace by the use of lime and oxide of iron as a flux. As the cinder from the higher furnaces is apt to contain oxide of lead, the use of oxide of iron is important, to exclude the former; but it is also important to form a fusible slag, which would not otherwise occur, from the tendency to form infusible sulphuret of calcium. It is evident, that in the low blast furnace the ore, &c. being merely piled up on a hearth exposed to the air, a mode of reduction must take place similar to that described under 1., consisting of alternate oxidation and reduction.

3. *Reduction with Iron* is performed in blast furnaces from 6 to 16 ft. high, or in reverberatories. It is usually performed on the unroasted galena, by mixing it with metallic iron and oxide of iron, either in the form of slack or iron ore. It would seem as if the process with iron were more economical than by the usual methods, but its use is as yet very limited. At Tarnowitz, in Upper Silesia, the ore is divided into *ore* and *shlich*, or fine-washed ore (Schlieche), which are separately reduced. The former is worked in a Krummofen, 5 ft. high; 100 cwt. ore, 36 poor lead slags, 12—14 iron granules, and 12 puddling slags are run through in 16 hours. The *shlich* is smelted in a blast furnace 16 ft. high; the charge for 40 hours being 100 cwt. *shlich*, 32 lead-stone (mixed sulphurets), 12—15 furnace scrapings, 10 iron granules, 24 puddling slags, and 100—120 lead slags of a previous operation. The lead-stone and scrapings are from the ore-smelting. At Poullaouen a reverberatory is employed, in which the ore is first roasted, and a portion of lead sweated out, then mixed with iron (iron and iron ore in some places), and subjected to a higher heat, to reduce and separate the balance of the lead. The theory of this reduction is very simple. Metallic iron readily abstracts sulphur from galena to form fusible sulphuret of iron, while lead is set free. Oxide of iron, in the ore or puddling slag, is also reduced by the heat and fuel, and operates similarly.

The lead obtained by these processes varies in quality, in consequence of various metals associated with the ore, such as copper, zinc, antimony, arsenic, &c., whereby it assumes a greater degree of hardness and sonorousness.

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The purest metal is obtained from a purer ore, and at the lowest temperature, such as that which flows out during the earlier stages of the reverberatory smelting, Virgin-lead, Jungfernelei; and as the heat is increased, the other metals reduce with the lead. The most important foreign ingredient in lead is silver, which is frequently present in such quantity as to repay the cost of its separation. See SILVER.

Lead is employed rolled into sheets, drawn or pressed into tubes, or put into form by fusion and casting. By a late process, tubes are ingeniously formed by forcing lead, just about the point of congelation through a collar with a solid cylinder in the centre.

The total annual production of lead in Europe is probably as follows:—

	Tons.
Great Britain	39,000
Spain.....	31,000
Hartz mountains.....	5,000
Austria.....	5,000
Prussia.....	1,600
Rest of Germany	1,600
France	800
Russia.....	700
Rest of Europe	300
United States	85,000
Rest of the world	8,000
Total	100,000

LEAD AND ITS NON-SALINE COMPOUNDS.

1. *Lead*. Sym. Pb. Eq. 104 (1294.5, O. = 100, or 103.76. H. = 1, *Lead*). To purify lead its oxide may be treated with ammonia to remove copper, and its nitric solution, after separating silver by nitrate of silver, repeatedly crystallized; the nitrate is heated to expel the acid, and then reduced by black flux. The pure oxalate, by ignition, yields the metal free from carbon.

Prop. It is bluish gray, with a high lustre, soft, very tough; cryst. in regular 8-hedra; spec. grav. 11.33—11.445; fusible at 617°—633°; boils at a white heat, burning in the air with a white light into litharge; kept fused in the air, it becomes covered with dross, into which it is wholly converted, if removed as fast as formed; it is a mixture of oxide, metallic lead, and sub-oxide? It oxidizes slowly in moist, not in dry air. Under water exposed to air free from carbonic acid, it forms hydrated oxide, which dissolves in the water; in common air containing carbonic acid, the hydrate at first formed is changed into a hydrate-carbonate. If the water contain salts, the oxidation is less rapid; and if these salts be sulphates or phosphates, a hard, white coating is formed on the surface, which protects the lead from farther oxidation. (*Bonsdorff*, *Christison*, &c.) Hence the necessity of charging lead-pipe, for conducting water for household use, with such solutions, previous to employing the water; where it has been found that the water takes up an appreciable quantity of lead.

A spring water conducted through 3,000 ft

of lead pipe into a leaden cistern, became so charged with lead as to affect the health of a family, and upon testing it, I found in it a notable quantity of lead. After charging the pipe with a solution of Glauber's salt, and then passing water through it, the latter yielded, after concentration of 200 to 1, scarcely a trace of a dark precipitate, which was only sufficient to prove by the blow-pipe that it was copper and lead, or tin. As it is usually necessary to concentrate water to test for the presence of lead, an error must be guarded against, which has been too often neglected, viz., the loss of the greater part of the lead-salt in solution, carried off in the vapor of water. Some preliminary experiments on this point, by Mr. C. Hartshorne and myself, proved, that if a salt of lead dissolved in a very large amount of water, and then evaporated, be compared with another, in which so much of the salt was dissolved as ought to be contained in the former concentrated liquid, the difference in the effect of sulphuretted hydrogen is very striking; for while it gives a decided precipitate in the latter, it either produces none in the concentrated liquid, or at most an indistinct, yellowish coloring. We found that the nature of the salt had an influence on its volatility. J. C. B.

2. *Oxides. a. Suboxide.* Oxalate of lead heated in a retort apart from the air, to 570° , forms the suboxide as a black powder, from which mercury extracts no lead, and sugar no oxide of lead.

b. Oxide of Lead. Protoxide, Massicot, Litharge, Bleiglätte. It may be obtained pure by igniting nitrate of lead. On a large scale it is made by calcining lead, dross, tailings of white lead, &c., in a reverberatory at a low heat (nearly 600°), with the free admission of air; and as an incidental product in the cupellation of lead for silver. It may be obtained crystallized by the slow cooling of fused litharge; by solution in, and crystallization from caustic alkali; by boiling the hydrate with a small quantity of potassa. It presents various shades of color from a light yellow to a red and brownish yellow, but its streak has the peculiar color of litharge, and contains no red-lead.

Prop. It is usually a yellowish powder, with an orange tone; fusible at a red heat, and congealing to a crystalline mass on cooling; volatile at a higher temperature. It is reduced to metal at a low temperature by hydrogen, carbonic oxide, and carbon; decomposed by chlorine, sulphur, and several sulphurets. The *hydrated oxide*, prepared by precipitation with ammonia, potassa, or soda, is a white crystalline powder, browning turmeric paper, slightly soluble in water (1 in 70,000), less soluble in water containing carbonic or sulphuric acid.

Salts. They are formed by direct action of the acid upon litharge, the nitrate and sulphate may be made from the metal and acid, the insoluble by double decomposition; silicate, borate, and phosphate may be made by fusion. The salts of lead are colorless, unless the acid be colored; the greater part of them insoluble in water, and these are generally soluble in

nitric acid; the soluble have a sweetish, astringent taste. Metallic lead in a brilliant branching form, lead tree, is precipitated from them by zinc and several other metals. Sulphuretted hydrogen, sulphuretted alkali, and some metallic sulphurets throw down black sulphuret of lead (brown if very dilute); a distinct yellowish tint is produced by sulphuretted hydrogen, with 1 pt. lead in 100,000 water. Caustic alkali, carbonate and phosphate of alkali throw down white hydrate, carbonate or phosphate, soluble in caustic potassa; with carbonate of soda a milkiness is produced with 1 lead to 50,000 water. Muriatic acid and soluble chlorides precip. white chloride from a strong, not from a dilute solution; sulphuric acid and sulphates give a white insoluble powder; iodides give a yellow precip. soluble in great excess of the iodide; chromate of potassa throws down from neutral salts yellow chromate of lead, insoluble in dilute nitric acid, from basic lead-salts the red chromate; infusion of galls gives a yellow precipitate; yellow prussiate of potassa gives a white precip.; red prussiate none; oxalates give the white oxalate in a dilution of 100,000 water.

c. Red Lead. Minium, Plumbate of oxide of lead. Form. $PbO + PbO_2 = Pb_2O_3$; or, if digested with neutral acetate of lead, it is $2 PbO + PbO_2 = Pb_3O_4$. (*Dumas.*) Prepared by heating metallic lead, carbonate, and dross in a reverberatory, to form litharge, grinding this between stones, and subjecting it again to heat, nearly 600° , in a reverberatory, with frequent *rabbling*, during which it absorbs oxygen from the air, and becomes red lead. *Orange mineral* is usually prepared by calcining white lead. The great difference in the color of red-lead, from a brownish to a brilliant vermilion red, is partly due to the mode of preparation, but chiefly to impurities, copper, antimony, iron, &c., in the materials employed. To make a good quality, the lead should be of good quality. Instead of heating it on the reverberatory hearth, it may be placed on iron trays, which are piled up in a reverberatory, and now and then rabbled. A *hydrate* is obtained by precipitating a solution of litharge in potassa, by a solution of plumbate of potassa; it is yellow, and easily changed into red-lead by gentle drying.

d. Peroxide of Lead. Binoxide, Plumbic acid. Form. PbO_2 . Formed by boiling red-lead with dilute nitric acid, which extracts oxide of lead; by fusing litharge with chlorate of potassa and saltpeter; by treating oxide of lead with chlorine, or hot solutions of lead-salts with chloride of soda, and removing chloride of lead by boiling with water or nitric acid. It is dark brown, insoluble, easily decomposed by heat alone or with combustibles, into litharge and oxygen. It acts as an acid, forming soluble alkaline salts, which precipitate insoluble plumbates.

Uses of the oxides. Litharge is extensively employed in the manufacture of flint and crystal-glasses; but minium is usually preferred, on account of its greater purity. (See Principles of GLASS making.) It is further employed with drying oils and oil varnishes,

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to render them drying in their character, its action in this case depending upon its forming compounds (plasters or lead-soaps) with the fat acids. Binoxide is used in organic chemistry for oxidizing, and in the arts for rendering phosphorus matches more inflammable.

Sulphuret. Found native at GALENA. It is easily formed by heating the metal or oxide with sulphur; or by precipitating lead solutions with sulphuretted hydrogen or sulphuretted alkali. By fusion it is lead-gray, metallic; by precipitation, black or brownish, according to the concentration. Its formula is PbS , containing 86.64 pr. ct. metal + 13.34 pr. ct. sulphur. It fuses by heat, and at a high heat vaporizes; by calcination in the air part of its sulphur is burned off as sulphurous acid, and there remains a mixture of lead and sulphate of lead. Heated to whiteness in a crucible with charcoal, it becomes a subsulphuret, which is resolved by heat into galena and metal. It is partly decomposed by vapor of water into sulphuretted hydrogen and lead. Moderately dilute nitric acid dissolves it, leaving sulphur; strong acid forms partly sulphate of lead, and fuming acid converts it wholly into sulphate. Chlorine does not act on it in the cold, and only partly by heat; strong muriatic acid forms chloride of lead. Metallic iron ignited with galena yields lead and fusible sulphuret of iron. Galena ignited with 2 or 3 pts. dry carbonate of soda yields metallic lead. As galena is usually associated with silex, the use of alkali with iron in the dry assay is advisable. But by the most careful assay the loss of lead varies from 5 to 10 pr. ct., which renders the wet assay superior in accuracy, although demanding much more time.

Phosphuret. Formed by throwing phosphorus on melted lead, resembles the metal in appearance, but is not malleable.

Alloys. They are usually harder and less tough than lead. A small amount of arsenic is employed to make lead shot. 1 pt. antimony to 4 or 5 lead is type metal; 129 antimony to 416 lead, = Pb_4Sb , is foliated, brittle, but loses no antimony by heating in a crucible. A small amount of bismuth renders lead tougher; in equal parts, the alloy is brittle; 312 lead with 21.3 bismuth, = Pb_3Bi , fuses at about 333° ; Pb_3Bi_2 has a single congealing point, 264° ; but Pb_2Bi has besides this another point, 295° , and $PbBi$ 289° . Tin and lead readily unite by fusion in all proportions, giving a harder, tougher, and more fusible metal than either constituent. 5 pts. tin to 1 lead is the common legal proportion for tin vessels used in Germany; soft solder varies from 2 tin with 1 lead to 1 tin with 2 lead. $PbSn_3$ has a single point of congelation at 368.6° ; the other alloys have a second point; $PbSn_{12}$ has it at 410° , $PbSn_6$ at 392° , $PbSn_4$ at 374° , $PbSn_2$ at 392° , $PbSn$ at 464° , Pb_2Sn at 518° , Pb_3Sn at 536° . (Rudberg.) Fusible metal.—Rose's, 2 pts. Bi + 1 pt. Pb + 1 pt. Sn fuses at 200° ; $PbBiSn_2$ (Regnault) fuses at 203° . Lead unites with some difficulty with iron, copper and nickel, to brittle alloys, and from copper it can be eliquated by heat alone. A good type alloy is said by Lassaigue to be 2 pts. lead, 1 pt. copper and 1 pt. antimony. A small proportion of lead is some-

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times added to brass to adapt it to the lathe, and is not rarely used in bell-metal. Lead unites readily with mercury to a solid, crystalline amalgam, which floats in the liquid mercury, and may be separated by pressing through buckskin. A lead rod bent into a syphon form will transfer mercury from one vessel to another. The rod is penetrated through with mercury and is still malleable; a portion of mercury remaining becomes the crystalline amalgam, which also floats in the mercury carried over. (J. Henry.) A small quantity of mercury added to Rose's fusible metal lowers its fusing point. Silver unites readily with lead. See CUPELLATION. Lead readily unites with gold, and the platinum metals to mostly brittle alloys. See these metals and ALLOYS.

HALOID SALTS.

1. **Chlorine.** *Chloride of Lead.* Form $PbCl$. Found native as COTUNNITE. Prepared by the action of muriatic acid on oxide or carbonate of lead, or by heat on the metal, or by precipitation from strong solutions of the salts. It is a white crystalline powder, soluble in 135 pts. water at 54.5° , in much less hot water; still less soluble in water acidulated with muriatic, and quite soluble in strong muriatic acid; it is also soluble in alkaline hyposulphites and acetates; scarcely soluble in alcohol of 76 pr. ct.; not at all in 94 pr. ct. alcohol. Fusible and not volatile at a red heat, apart from the air, but volatile with access of air, leaving oxychloride of lead, PbO , $PbCl$. Another oxychloride is formed by precip. subacetate by common salt, or by the action of oxide of lead on common salt; in the latter case, caustic soda is set free, containing a portion of lead-salt; form. $PbCl$, 3 PbO + HO ; the water is expelled by heat, leaving a white mass. Turner's patent yellow is an oxychloride made in this manner, which by fusion becomes yellow. Chloride of lead combines in a remarkable manner with other salts, with carbonic acid in CORNEOUS LEAD, with phosphoric and arsenic acids in NUSSIERITE, PYROMORPHITE, &c.

2. **Bromide of Lead.** $PbBr$. Formed by the action of bromohydric acid on oxide of lead, or by precipitation with an alkaline bromide. is a white crystalline powder, fusible to a red liquid, forming an oxybromide when heated in the air, slightly soluble in cold, much more in hot water and in acidulated water. The oxybromide, PbO , $PbBr$ is yellow.

3. **Iodide of Lead.** PbI . Obtained by precipitating a salt of lead by iodide of potassium. According to Boudet, when acetate of lead is used, the decomposition is imperfect, and the nitrate is superior to it. The crystals are finer if the solutions be dilute; and to obtain the finest crystals, according to Hoppf, 1 pt. iodide of potassium is dissolved in 10 pts. water, iodine added to the solution until it appears yellowish brown, and a dilute solution of the lead-salt gradually added. It forms gold or orange-yellow crystalline laminæ, which become dark reddish brown by heat, and fuse to a liquid of the same color, giving off iodine when heated in the air, and forming oxidized

of lead. It is soluble in 1235 pts. cold, in 190 pts. boiling water, in cold and hot solution of salammuniac, in concentrated solutions of alkaline iodides. Basic iodides or -oxidides are obtained by precip. iodide of potassium with basic acetates of lead. Form. from PbO , PbI to $5 PbO$, PbI . By the action of hydriodic acid on lead or the iodide of lead, a combination is formed in white, silky needles, easily decomposed by heat or water.

4. *Fluoride*. Formed by the action of fluohydric acid on oxide, carbonate or acetate of lead, is a white, amorphous powder, fusible, almost insoluble in water. Caustic ammonia extracts so much acid that a basic salt remains. A white fluochloride is formed by the action of fluoride of sodium and chloride of lead in hot solution.

OXYSALTS.

1. *Carbonate of Lead*. Syn. White lead. *Ger.* Bleiweiss. *Fr.* Ceruse. The neutral carbonate occurs native as WHITE LEAD. The artificial compound, a hydrocarbonate, is largely manufactured according to one of three principles, by the air, water, and carbonic acid acting on metallic lead; by decomposing a salt of lead with carbonic acid; or by decomposition with alkaline carbonates.

a. *Triturating Processes*. Several processes have been employed for preparing white lead, in which the finely-divided metal is moistened and exposed to air alone, or to air and carbonic acid, with constant agitation. A little vinegar has also been used to acidulate the water, attended with somewhat better results. But the white lead produced by these methods is mostly a simple hydrocarbonate of lead, PbO , $HO + PbO$, CO_2 , of inferior whiteness, with very little body or power of covering a surface, and very liable to become yellow by exposure. The little body it possesses must be ascribed to its more crystalline character, and greater transparency. From all experiments made with white leads, it appears that the more highly carbonated they are, the less easily are they decomposed or liable to tarnish; and hence this kind, which is the most hydrated, is most liable to change in the atmosphere.

b. *Precipitation by Carbonic acid*. Carbonic acid, passed through a solution of neutral acetate of lead, precipitates a small quantity of white lead, but soon ceases from the increasing amount of free acetic acid. The same gas passed through a solution of basic acetate throws down a larger quantity, until there is an excess of free acetic acid. Thenard's process is based on this fact, which also explains all the ordinary methods by which white lead is made. A solution of neutral acetate of lead is digested with litharge, which it dissolves, forming a basic acetate. This is precipitated by carbonic acid until the solution becomes acid, when it is again digested with litharge, and again precipitated; so that the acetate at first used continues constantly in use, except the ordinary manufacturing waste, and merely acts as a medium for transferring carbonic acid to the oxide of lead. This process is carried out practically in France and Sweden.

Clark's and Richard's Patents (*Journ. Franklin Inst.* xxv. 232) consist in hanging up sheets of lead in an apartment, into which carbonic

acid, air, and steam are introduced, and vinegar is put in a trough at the bottom of the apartment. The heat of the apartment vaporizes the vinegar, which attacking the surface of the metal, disposes it to oxidize more rapidly, and form a basic salt of lead. At the moment of its formation, it is partly decomposed by carbonic acid, as in Thenard's process, and the acetic acid set free acts upon another portion of the metal. The steam or moisture present enables the particles of matter to move freely and undergo chemical changes.

The Kremser white is prepared at Klagenfurth, Carinthia, by hanging up sheets of lead in wooden troughs, in the bottom of which are put various mixtures, such as wine-lees and vinegar, all capable of forming carbonic acid by fermentation. The troughs are closed up, and placed in a chamber which is heated to about 100° . The sheets of lead become corroded and converted into white lead, which is ground, washed over, and dried for the market.

The old Dutch method, which is still most extensively pursued of all others, is based on the same principle. The lead is cast into thin sheets or thicker rings, and placed in earthen pots, so as to rest on 3 projecting points, about 3 lbs. of lead being put in every pot. A pint of tolerably strong vinegar is poured into the bottom of the pot, and does not reach the projecting points nor touch the metal. The pots are placed in rows, forming a layer upon a bed of tan or dung, and from 6 to 10 such layers are piled up in the fermenting shed, and surrounded with tan or dung. By the fermentation of the latter, heat and carbonic acid are produced, the former of which slowly vaporizes the vinegar at the bottom of the pots, induces the formation of oxide and simultaneously of carbonate of lead. The time required for the process is, according to the season, 6 weeks more or less. When the beds are broken up, the sheets of lead are more or less corroded, within a small fraction of the amount employed, and the vinegar has generally disappeared from the pots. We have seen the corrosion of a solid pig of lead, laid in a bed, to the depth of half an inch.

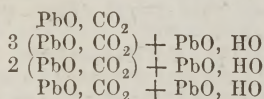
Several other variations of this process have been proposed and carried out, but generally with very partial success. One of the best of these is that of Benson, in which litharge was moistened with $\frac{1}{30}$ its weight of vinegar, introduced into stone troughs, and heated carbonic acid, derived from the combustion of coke, passed over it, while the contents were violently agitated. Another process uses nitrate instead of acetate of lead.

It is evident, upon a moment's reflection, that the above processes all depend on the same principle as Thenard's, viz., the formation of a basic salt and its decomposition by carbonic acid, until a neutral salt is formed, which again reacts upon the metal or litharge to produce a basic salt, and so on. But there should be finally a neutral salt remaining. It is true that acetate is always washed off in grinding and washing the crude white lead, but the amount is very small; and the reason is, that while acetic acid is set free by decomposition with carbonic acid, a portion of it escapes, so

that towards the close of the operation there is but little remaining. That air is necessary to the formation of oxide, may be shown from Richard's patent, by which a fair article of white lead was made, and from the necessity of having the pots porous, for if well glazed the corrosion is imperfect. That the acetic acid does not furnish carbonic acid or oxygen by its decomposition, is shown from the fact that in each pot, by the Dutch method, there are about 3 lbs. lead and a pint of vinegar, containing about 1 oz. anhydrous acetic acid; or, in a large bed of 10 layers and 600 in a layer, 18,000 lbs. lead and 6000 oz. dry acetic acid. The whole of the carbon of this acid could only form carbonate with 3000 lbs. lead ($\frac{1}{6}$ of the whole), or the whole oxygen of the acid could only oxidize 2270 lbs. lead ($\frac{1}{8}$ of the whole). But during the whole process of weeks' duration, vapor of vinegar is constantly escaping (and probably acetone), so that this acid could not possibly contribute much towards the oxidation or carbonation of the lead.

c. Precipitation by Carbonates. Several processes on this principle have been proposed, but not successfully carried out, owing to a complicated combination of them with other branches of manufacture. In one of them, nitrate of soda is decomposed by sulphuric acid forming nitric acid and sulphate of soda; the last is decomposed to form carbonate of soda, and the nitric used to make nitrate of lead from the metal or litharge. The carbonate of soda is then added to the nitrate of lead, precipitating carbonate of lead, while nitrate of soda enters the solution and is obtained by evaporation, to be again treated as before.

Prop. By whatever process made, white lead should have a very soft, velvety feeling, when rubbed between the fingers. According to Hochstetter, it consists of small globules from 1000000 to 10000000 of an inch diameter, those produced by Thenard's process being larger and more translucent than the others. It has the greatest body of all white pigments, and is used both as a vehicle to convey, and as a diluent to other colors. Thenard's has less body, but when a surface has had several coats of it, it appears whiter than the common white lead. According to Berzelius, Mulder and others, the carbonate precipitated by an excess of carbonated alkali, is the neutral salt. The following is a tabular view of the various white leads:—



The first is the neutral salt, made by precipitation with carbonated alkali; the last by the trituration processes. The 3d is about the composition of the white leads of commerce, containing $86\frac{1}{2}$ pr. ct. oxide of lead, $11\frac{1}{2}$ pr. ct. carbonic acid, and $2\frac{1}{2}$ pr. ct. water. The 2d is very highly carbonated for a white lead made in the usual way. For a fuller view of the manufacture of white lead, see an essay by J. C. B., in the *Journal Franklin Inst.*, 3d Series, Vol. iii.

2. Nitrate of Lead. Formed by the action of nitric acid on the metal or oxide, crystal-

lizes in the regular form, permanent in air, soluble in 1.989 pts. water at $63\frac{1}{2}^\circ$, with a spec. grav. = 1.3978, in 1.585 pts. at $76\frac{1}{2}^\circ$, less soluble in nitric acid, insoluble in alcohol; by heat it yields oxygen and red oxide of nitrogen, de-flagrates on burning coals. When other salts are precipitated from it, it tends to mix with them, as nitrate-fluoride of lead. Its form is PbO, NO_3 , containing 67.4 pr. ct. PbO . A basic salt, $\text{PbO, NO}_3 + \text{PbO, HO}$, is obtained in crystals by digesting the neutral salt with litharge or white lead. Two other more basic salts are formed by precipitating with ammonia. A nitrate-nitrite is formed by digesting with increasing heat 100 pts. nitrate in solution with 70 pts. lead-shavings, and crystallizing; yellow crystals of the form. $2 \text{PbO, NO}_3 + 2 \text{PbO, NO}_2 + 4 \text{HO}$. A neutral nitrate-nitrite is obtained by passing carbonic acid through the preceding, in warm water; and a still more basic nitrite by digesting with more lead.

3. Chlorate and Perchlorate, formed by direct solution of oxide in the acid, are soluble and crystallizable. The chlorite is formed by precipitating nitrate of lead by chlorite of baryta, containing free chlorous acid. Bromate crystallizes from solution of white lead in the acid; PbO, BrO_3 , HO. Iodate is precipitated from nitrate of lead by iodic acid or an alkaline iodate.

4. Sulphate, PbO, SO_3 , formed by the action of sulphuric acid on lead or oxide of lead, or by precipitation with the acid or a sulphate. A white powder, fusible without decomposition, but easily decomposed by ignition with charcoal, silica, or clay; scarcely soluble in water, more so in water containing sulphuric acid, and still more in oil of vitriol; somewhat soluble in muriatic and nitric acids, with partial decomposition; soluble in ammoniacal salts, in 47 pts. acetate, and largely in the tartrate; very soluble in hot sulphate of ammonia, and crystallizing out as a double salt. It fuses readily with chloride of lead and fluor spar, in different proportions. The sulphite formed by double decomposition is insoluble in water. Dithionate (hyposulphate), formed direct, crystallizes with the form. $\text{PbO, S}_2\text{O}_5$, 4 HO. Dithionite (hyposulphite) is formed by slowly adding a lead salt to an alkaline dithionite; it forms double salts with alkaline and earthy dithionites. There is also a trithionate and tetrathionate of lead.

5. Phosphate, 2PbO, PO_5 , is precipitated by adding common phosphate of soda slowly to a solution of chloride of lead; fusible, insoluble in water and acetic acid, soluble in nitric acid, and caustic fixed alkali, decomposed by muriatic and sulphuric acids. An acid phosphate is similarly obtained from the acid phosphate of soda; and a basic salt by digesting the neutral with ammonia. Hypophosphite is formed by solution of freshly-precipitated carbonate in the acid. Phosphite is obtained by neutralizing terchloride of phosphorus by ammonia, adding a hot solution of chloride of lead, washing out the excess of chloride, and drying in vacuo.

6. Borate, PbO, 2 BO_3 , is fusible, slightly soluble in water, not in water containing a soda salt; 112 pts. oxide of lead fuse with 24 pts. boracic acid to a very soft, yellow glass, of

spec. grav. 6.4, which softens under boiling oil; with 48 pts. acid to a harder and less colored glass; with 72 pts. acid to an almost colorless glass, as hard as flint-glass, and much more refractive.

7. *Silicate*. Silix fuses with oxide of lead to a yellow glass. This is the basis of flint and crystal glass, and of artificial gems or strass, the last of which has the form. $\text{KO}, \text{SiO}_3 + 3(\text{PbO}, \text{SiO}_3)$. See Acetate of Lead, under ACETATES.

LEADHILLITE. *Min.* Sulphatotricarbonate of lead. Cryst. Oblique Rhombic, prismatic, with perfect basal cleavage. $\text{H.} = 2.5$. $\text{G.} = 6.2 - 6.5$. Color white, yellowish, and greenish; lustre on cleavage pearly, otherwise resinous; transparent, translucent; sectile. It fuses readily, and easily reduces; effervesces in nitric acid, and leaves white sulphate of lead. Form. $\text{PbO}, \text{SO}_3 + 3(\text{PbO}, \text{CO}_2)$. It occurs at Leadhills, Scotland.

LEAD VITRIOL. *Min.* Anglesite. Cryst. Right Rhombic, vertical and horizontal prisms, and end-planes; also granular. $\text{H.} = 3$. $\text{G.} = 6.259 - 6.298$. White, sometimes tinted; lustre adamantine; transparent, opaque; very brittle, with conchoidal fracture.

Decrepitates by heat; fuses in the outer flame to a clear glass, becoming milk-white on cooling; reduces in the inner flame; reduces with soda and silix to a hepar. Its powder is wholly soluble in caustic potassa. Form. PbO, SO_3 . It is usually contained in cavities in galena, and is distinguished from white lead by not effervescing with nitric acid. It occurs at Leadhills, Wanlockhead, Scotland; in Cornwall, on the Hartz, &c. In U. S., Southampton, Mass.; St. Lawrence Co., N. Y.; Perkio-men, near Phila., Penn.; lead mines of Illinois, Wisconsin, and Missouri.

LARD. The adipose matter of the omentum and mesentery of the hog. It is rendered either in the open pan or in steam tanks. The latter method furnishes a purer and whiter article, which being thus partially granulated, is ready to be pressed for its oil, without the necessity of re-steaming. Lard rendered in the open pan is liable to be scorched, and yields a larger proportion of cracklings. For the method of refining these, and also for the most approved plans of rendering lard, see Morfit's "*Applied Chemistry*."

Prop. Corn-fed lard is more consistent and of better quality than either the mast or slop fed. Fuses at 81° , spec. grav. 0.938. Anhydrous boiling alcohol dissolves 2.80 pr. ct. Becomes yellow and rancid on exposure, and by saponification yields 9.0 glycerin and 94.65 pr. ct. of oleic, margaric, and stearic acids.

LECANORIN. See LICHENS.

LEDERERITE. See CHABAZITE.

LEDERITE. See SPHENE.

LEELITE. See FELDSPAR.

LEGUMIN. Syn. Vegetable Casein. Found by Braconnot in the fleshy cotyledons of the seeds of leguminous plants. It may be extracted from ripe peas, beans, or lentils, by softening and braying them in water, decanting the liquid from the subsident starch, and evaporating it until transparent mucous pellicles appear on the surface. These diaphanous pellicles when washed, while still moist, with boil-

ing alcohol, acquire a white color, and do not affect litmus paper.

Prop. Insoluble in alcohol and ether. Its aqueous solution is not coagulable by heat, but by exposure acquires (lactic) acid and then coagulates. From its solutions in the vegetable acids it is precipitated by the mineral acids; an excess of the latter, however, redissolves the coagula, which are compounds of casein with the acid. It also dissolves in alkalies, and the compounds which it then gives with the earthy and metallic salts are insoluble in water.

In its apparent tartaric solution, the nitrates of baryta and lead, chloride of calcium, sulphates of iron and copper produce precipitates, in which the salt is almost always taken up as such.

According to Liebig it is identical with animal casein. Its composition, as determined by Dumas, Cahours, and other chemists, probably from impure materials, is shown to be incorrect by the recent investigations of Noad, who also declares it to be a protein compound, identical in composition with fibrin and albumen. *Chem. Gaz.* v. 357.

LEHUNTITE. See NATROLITE.

LEMANITE. See SAUSSURITE.

LEMONS, SALT OF. Bincoxalate of potassa. See OXALIC ACID.

LEMONS, OIL OF. The oil obtained by distillation of the peel of *Citrus limonum*, though less odorant is purer, and not so liable to decomposition as that procured by expression.

Formula C_{10}H_8 , spec. grav. 0.847. The spec. grav. of the vapor is 4.80 to 4.87. Boils at 343.4° , but when distilled its point of ebullition and the spec. grav. of the distillate increases to .877. The ordinary oil, unlike the rectified, at -4° deposits white crystals, probably hydrated.

Oil of lemons acted upon by chlorine gas, is transformed into a solid and liquid compound. The first is the *Camphor* of the lemon, and is separable by lessening the solvent power of the liquid camphor, by a diminution of temperature. It melts at 113° , sublimes at 122° , and at a higher temperature is partly decomposed. The formula, $\text{C}_{10}\text{H}_8\text{HCl}$, expresses the composition of both of these compounds. They are decomposable by the alkalies, and furnish two isomeric oils, *Citrène* and *Citrylene*.

Citrène. Syn. Citronyl. Spec. grav. 0.847. Boils at 329° . Spec. grav. of vapor 4.73.

Citrylene. Syn. Citryl. Spec. grav. 0.88. Boils from $334^\circ - 347^\circ$.

LENZINITE. See HALLOYSITE.

LEONHARDITE. Probably LAUMONITE.

LEPIDOKROKITE. See BROWN HEMATITE.

LEPIDOLITE. See LITHIA MICA.

LEPIDOMELAN. *Min.* A hexagonal mica. $\text{H.} = 3$. $\text{G.} = 3$. Black, with green streak; lustre adamantine; translucent in thin leaves. By heat it becomes pinchbeck-brown, and fuses to a black, magnetic enamel; soluble in muriatic and nitric acids. Form. $3\text{RO}, \text{SiO}_3 + 3(\text{R}_2\text{O}_3, \text{SiO}_3)\text{RO} = 12\text{FeO} + 9\text{KO}; \text{R}_2\text{O}_3 = 27\text{Fe}_2\text{O}_3 + 11\text{Al}_2\text{O}_3$. Found at Persberg, Wärmeland.

LETHEON. *Med.* From *Λθηω*, to forget, because its inhalation, by patients, renders them unsuspceptible of pain whilst undergoing surgical

operations. Highly rectified sulphuric ether (see ETHER as *Letheon*) was first proposed for this purpose, but more latterly Dr. Simpson, of Edinburgh, (*London Athenæum*, Nov. 1847,) recommended CHLOROFORM (see also Perchloride of FORMYL) as a much better substitute, being of more ready application, and freer from the injurious effects which ether is liable to produce upon certain temperaments. See recent works on "*Anæsthesia*," by Simpson and Warren.

LEUCHTENBERGITE. *Min.* Foliated. $H. = 2.5$. $G. = 2.71$. White or yellowish; transparent, pearly. It gives with borax and mic. salt the reaction of iron and silica, and fuses to a slag with soda. Form. $3 \text{ MgO}, \text{SiO}_3 + \text{Al}_2\text{O}_3, \text{SiO}_3 + 3 (\text{MgO}, \text{HO}) (?)$. It may be altered Chlorite.

LEUCIN. $\text{C}_{12}\text{H}_{13}\text{NO}_4$. See PROTEIN and CASEIN. Hjenko's and Cahour's recent researches (*Liebig's Annal.* lxxiii. p. 264; *Comptes Rendus*, 1848) confirms the opinion of Mulder, that it is identical with aposepedin.

LEUCITE. *Min.* White Garnet. Cryst. Regular; usually as Pl. VIII. fig. 4, cleaving imperfectly into fig. 2, and also into the cube. $H. = 5.5 - 6$. $G. = 2.48 - 2.49$. White and grayish; vitreous, translucent; brittle with conchoidal fracture. Infusible and unalterable, giving a blue with cobalt-solution; in fine powder, perfectly soluble in muriatic acid. Form. $3 \text{ KO}, 2 \text{ SiO}_3 + 3 (\text{Al}_2\text{O}_3, 2 \text{ SiO}_3)$; there is a trace of soda in the potassa.

Local, &c. In ancient lavas on the Rhine, and in modern lavas of Vesuvius. It was the first mineral substance in which potassa was proved to exist; and by Klaproth.

LEUCOLE. Formula $\text{C}_{18}\text{H}_8\text{N}$ (*Hoffman*), or $\text{C}_{18}\text{H}_8\text{N}$ (*Laurent, Gerhardt*). A colorless oil of a bitter almond taste, forming one of the products of the destructive distillation of COAL. Congeals at -4° , boils at 462° , and resinifies on exposure; spec. grav. 1.081. Is more soluble in hot than cold water, and mixes in all proportions with alcohol, ether and wood-spirit, acetone, and the oils generally. Its refractive power is 1.645; with the acids it forms salts, of which the nitrate crystallizes with most facility.

The double chloride of platinum and leucole, $\text{C}_{18}\text{H}_8\text{N} + \text{ClH} + \text{Cl}_4\text{Pt}$, is a light orange, crystalline powder, slightly soluble in water, alcohol, and ether.

A distinctive property of leucole is its power of resisting a high heat. According to Hoffman, it is positively identical with QUINOLIN, and gives, when pure, with chromic acid, the yellow crystalline precipitate which Gerhardt describes as characteristic of the latter substance.

LEUCOPHANE. *Min.* Imperfectly crystallized; 4-sided prism. $H. = 3.5$. $G. = 2.974$. Pale green to wine-yellow, with white streak; vitreous; thin fragments transparent; phosphorescent by heat; electric. Fuses alone or with borax to an amethyst glass, and leaves silica in mic. salt; heated with fused mic. salt in an open tube, it yields fluorine acid. Form. $\text{NaFl} + 3 \text{ CaO}, 2 \text{ SiO}_3 + 3 \text{ GO}, \text{SiO}_3 (?)$. It occurs in a rock off the coast of Norway.

LEUCOPYRITE. *Min.* Glanzarsenikkies, Arsenikeisen. Cryst. Right Rhombic; pris-

matic, also massive. $H. = 5 - 5.5$. $G. = 7.228 - 7.337$. Color between silver-white and steel-gray; metallic; brittle with grayish black streak.

On charcoal it yields a strong arsenical odor, leaving a black magnetic mass, and gives in a closed tube sublimed arsenic, soluble in nitric acid with separation of arsenious acid. Form. nearly FeAs , sometimes containing cobalt and nickel. *Local.* Schlading, Styria; Reichenstein, Silesia; Bedford Co., Pennsylvania.

LEUCOTURIC ACID. Formed by the metamorphosis of alloxanic acid in solution, by boiling.

LEVIGATION. The process by which the more impalpable portions of a powder may be separated. It is practised by grinding the substance, previously made into a paste with water, under a muller or between stones, throwing the levigated matter into water, stirring the mixture, and after partial subsidence decanting the supernatant liquid. This, on settling, deposits the finely-levigated powder.

LEVYNE. See CHABAZITE.

LEYDEN JAR. See ELECTRICITY.

LIBAVIUS' FUMING LIQUOR. The chloride of TIN.

LIBETHENITE. *Min.* Prismatic Olivenite. Cryst. Right Rhombic. $H. = 4$. $G. = 3.6 - 3.8$. Dark olive-green; resinous; subtranslucent; brittle with conchoidal and uneven fracture. Moistened with muriatic acid, it colors the blowpipe flame blue; fuses and reduces partly alone, entirely by fusion with lead; soluble in nitric acid and in ammonia. Form. $4 \text{ CuO}, \text{PO}_5 + \text{HO}$, or better $3 \text{ CuO}, \text{PO}_5 + \text{CuO}, \text{HO}$. See OLIVENITE and PHOSPHORCHALCITE. It occurs at Libethen, Hungary.

LICHENS. *Chem.* An order of perennial plants, the foliaceous species of which are used in medicine, their nutritive, demulcent, and emollient properties being due to the amylaceous matter (*Lichenin*) which they contain, and their tonic virtues to a bitter principle, CETRARIN. In some countries they are used by the poor as food. In composition they are very analogous, but certain ones differ from others in yielding, by treatment with ammonia, brilliant color stuffs, and hence their value as dyes. In this way the *orchil* or *litmus*, much used as a delicate test for the presence of acids, which immediately changes its blue color into red, is prepared from an aqueous decoction of the *Rocella tinctoria* and *Leconora tartarea*. Schunck (*Lond. Chem. Society's Memoirs*, vol. i. p. 72) found in the *Genera Lecanora, Urceolaria, Variolaria*, &c., 1. a white, crystalline substance, insoluble in water, but soluble in alcohol and ether, which he called *Lecanorin*, $\text{C}_{15}\text{H}_8\text{O}_8$, very similar to the *Erythrin* of Heeren and *Erythrinin* of Kane, but of different composition; its solution in alkalies is converted by exposure into *orcin*, $\text{C}_{16}\text{H}_{11}\text{O}_7$, and carbonic acid, and ultimately acquires a deep purple color, from which acids precipitate a red coloring matter. The *orcin* thus formed, first discovered by Robiquet in lichens, is crystallizable and in itself capable of being transformed by the action of ammonia and oxygen into a true coloring matter, in which reaction all the original combinations are altered. It is also obtained pure by boiling *orsellesic acid* in water for an

hour, carbonic acid being expelled. 2. *Pseudorythrin* (erythrin), $C_{20}H_{12}O_8$; and 3. a fatty substance, dropping in pearly white scales from an alcoholic solution, which form soap with alkali, and are insoluble in water and ether.

Rochleder and Heldt found *Usnin* or *Usnic* acid in the *Lichen rangiferinus*, *Ramalina calicaris*, *Usnea barbata*, and Knapp obtained it from the *Usnea florida*, and (*Chem. Gaz.* ii. 160, 180) almost all the species of *Cladonia*. It is also yielded by many other species of *Lichen*, in large quantity by the *Parmelia sarmentosa* and *Lecidea Geographica*.

Usnic acid, $C_{38}H_{17}O_{14}$, forms lemon-yellow crystals which fuse at 392° , and by their property in common with the yellow and green resins accompanying it in the plant, of becoming red by ammonia and exposure to air, acts an important part in the alterations of color of many lichens. Is insoluble in water, sparingly soluble in alcohol, and readily in boiling ether and oil of turpentine. It forms salts with the bases, of which those with the alkalis are crystallizable.

Herberger has also separated from the *Lichen parietinus* a crystallizable, yellow, coloring matter, *Chrysophanic acid*, $C_{16}H_4O_3$, soluble in cold ether and alcohol with a yellow color, and in alkalis with a red color, from which latter it is precipitated yellow by acids. There is an additional coloring substance in the lichen, but it is viscid, uncrystallizable, and insoluble in alcohol. The body which imparts the green color to the spherical cells of the *Cetraria Islandica*, has been named by Knapp and Schniderman (*Ann. der Chem.* lv. p. 144) *Thallochlor*, and by Francis *Chlorothalle*.

In a recent examination of the proximate principles of lichens, Stenhouse discovered that the coloring matter could be extracted without the aid of ammonia. By the process adopted, (*Chem. Gaz.* vi. 125), he obtained from *Rocella tinctoria* white crystals of *Orsellinic acid*, $C_{32}H_{15}O_{13} + HO$, and an indifferent crystallizable substance, *Rocellinin*, $C_{38}H_{17}O_{15}$; from the *Rocella Montagnei*, *Erythric acid*, $C_{20}H_{10}O_9 + HO$, and *Pseudo-orcein*, $C_{10}H_{13}O_{10}$; and from the *Evernia Prunastri*, *Evernic acid*, $C_{34}H_{15}O_{13} + HO$. From these researches, Stenhouse proposes to extract the coloring principle of lichens, and render it portable for commercial purposes, by cutting them into small pieces, macerating in milk of lime, neutralizing with muriatic or acetic acid, collecting the gelatinous precipitate on cloths, and drying it at a gentle heat.

LIEVRITE. *Min.* Yenite, Ilvaite. Cryst. Right Rhombic; also massive, columnar, granular. $H. = 5.5 - 6$. $G. = 3.82 - 4.06$. Iron-black; submetallic; opaque; brittle. Fusible to a black, magnetic globule; gives the reaction of iron with the fluxes; soluble in warm muriatic acid. Form. $3 (3 FeO, SiO_3) + 2 (Fe_2O_3, SiO_3) (?)$. *Local.* Elba, Norway, &c.; Cumberland, R. Island; Essex Co., N. Y.

LIGAMENTS. The elastic membranes connecting the extremities of the movable bones, are formed of cellular and elastic tissue, and may be classified among those that yield **GELATIN**, when boiled in water.

LIGHT. *Phys. Chem.* A highly elastic,

imponderable fluid, or the undulations of an æther. The sun's rays produce luminous, heating, electric, magnetic, and chemical effects; hence some have supposed that there are several different kinds of rays. The rays of heat are differently and less refrangible than those of light; thus with a prism of flint-glass, the greatest heat is observed outside of the red ray, with one of crown-glass in the red, and with one of water in the yellow.

Chlorine unites with hydrogen by the action of light, under white and blue, but not under red glass; lime-water precipitates chloride of platinum in colorless or violet light, not in yellow or red. Peroxalate of manganese is changed to protoxalate in sun-light, slowly in blue or violet light; peroxalate of iron is similarly reduced in white, violet, and blue, but not in yellow or red, even at a boiling heat. In like manner numerous decompositions have been observed, which are stronger in violet and blue than in red or yellow light; but a solution of blue iodide of starch is wholly decolorized in the yellow and green rays of the spectrum, slightly in the red and blue, and not at all in the violet. The action of the colored spectrum on sensitive paper, containing chloride of silver, is strongest in the violet, but it extends beyond the violet and red, differing according to the nature of the prism. Daguerre's bromide of silver paper is not altered by heat, but very sensitive to light.

It appears, then, that there are three kinds of rays in sun-light, calorific, luminous, and chemical rays, of which the first are least, the last are most refrangible, and the luminous intermediate in this respect. The chemical action of light has been made use of especially in the **DAGUERRETYPE** processes, and in uniting chlorine with organic bodies. Phosgen (produced by light) gas was produced by the action of light on carbonic oxide. The polarization of light has been elegantly applied, by Biot, to the analysis of sugars, which would otherwise be very difficult of accomplishment. For a description of the method, see "*Morfil's Manipulations*," p. 398.

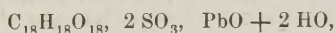
LIGNIN. Syn. Woody fibre. Cellulose. The solid frame-work of plants, varying in physical properties with the vegetable whence derived, being hard and compact in wood, and fibrous and flexible in flax, cotton and the like. It is insoluble in the usual solvents, and remains after plants have been successively treated with ether, alcohol, water, dilute acids, and alkalis.

Prop. When dried at $300^\circ - 350^\circ$, its formula is $C_{12}H_8O_8$, (*Prout*.) According to Payen, however, woody fibre consists of two portions, viz., *Cellulose*, $C_{12}H_{10}O_{10}$, constituting the tissue of the cells, and lignin proper, filling the cavities, $C_5H_4O_{20}$, of the former.

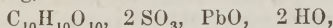
There are some properties peculiar to each, but their general behavior is the same. Thus, for example, cellulose is insoluble in nitric acid, while lignin dissolves in that reagent. It moreover is isomeric with starch, and is dissolved by sulphuric acid without being blackened, and transformed into dextrin. Another distinctive characteristic is, that the cell-walls which are colored brown by the mere action of the iodine, appear blue under the microscope,

after the addition of sulphuric acid, while the contents of the cell remain brown. Woody fibre doubtless differs from starch mainly by its state of aggregation, by which it resists the action of reagents; for as soon as its physical organization is destroyed, it then yields to energetic agents.

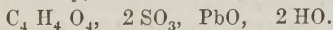
Cold water is inert, but by boiling disaggregation ensues. Air and moisture transform it into carbonic acid and HUMUS. By dry distillation it yields the same products as Wood. Torrefaction destroys its physical properties, and renders it analogous to gum, soluble in water. Weak nitric acid transforms it into oxalic acid, but that which is concentrated produces *xyloidin*. See GUN COTTON. Sulphuric acid varies in its action according to time, quantity, and state of dilution. When concentrated it carbonizes and generates sulphurous, acetic, formic acids, and water. By heating in a closed vessel, and under certain circumstances in an open vessel, with sulphuric acid, fibre is converted into dextrin and grape sugar and *ligno-sulphuric acid*. This acid, forming soluble, uncrystallizable salts with the oxides of lead and barium, varies in composition with the duration of the reaction; for example, that formed by short contact is—



becoming, after 12 hours' contact,



and ultimately, after 24 hours,



Blondeau.

Woody fibre resists the action of diastase. With corrosive sublimate, deutosulphate of copper, and acetate of iron it unites, partially decomposing them. It also combines with hydrate of alumina, peroxide of iron, and many coloring matters. *Fungin* and MEDULLIN are doubtless only physical modifications of lignin.

LIGNITE. *Geol.* See COAL. A late investigation of brown coal with the woody structure, by Schrötter, gives its $G. = 1.28$, $H. = 2$; it yields $\frac{1}{4}$ its weight of coke by dry distillation, while water, acetic acid, and a tough pyroil pass over. Ashes = 2.57 pr. ct. The combustible matter has the composition $C_{12}H_7O_3$. Extracted by ether, the residue is $C_{11}H_7O_6$, and the ether extract contains HARTIN.

LIGURITE. *Min.* Cryst. Oblique Rhombic. $H. =$ above 5. $G. = 3.49$. Apple-green; transparent, translucent. It is a silicate of lime and alumina, from the Apennines of Liguria.

LIMBELITE. See CHRYSOLITE.

LIME. Oxide of CALCIUM.

LIMESTONE. *Geol.* Extensive and widespread formations of carbonate of lime occur from the oldest to the latest geological periods of deposited rocks, which are all termed limestone. When sufficiently compact and capable of receiving a polish, they are termed marbles. The white pulverulent formation of the upper secondary period is chalk. Those solid, stony formations, which are neither marble nor chalk, are more especially called limestones. The prevailing color is bluish gray, due to the carbonaceous matter disseminated through them.

Magnesia is an almost constant, and often abundant constituent of limestone. All, except those of a highly crystalline structure, abound in animal organic remains; and the crystalline have contained them, but have, subsequent to their formation, suffered alteration. They are therefore included with metamorphic rocks. See CALCAREOUS SPAR.

LIMONE. Syn. Limonin. Found by Bernays in orange and lemon pips, and exists probably in the seeds of all the *Aurantaceæ*.

Prep. Treat the powdered seeds with cold alcohol, evaporate the tincture, and filter while hot.

Prop. A white, crystalline, bitter powder, sparingly soluble in water, ether, and ammonia, very soluble in alcohol and the hydrated salts, and less so in the mineral acids. From its potash solution the acids precipitate it unaltered. It is apparently not a base, but concentrated sulphuric acid dissolves it with a blood-red color. From this, as well as its alcoholic and acetic solutions, it is thrown down unaltered by water. From acetic acid it crystallizes readily. The alcoholic solution has a neutral reaction. Heated to 302° it undergoes no change, but at 471° melts. The indifference of limone to deoxidizing agents is a remarkable property, it being precipitated in its natural state, by water, from its solution in hot, concentrated nitric acid. *Schmidt*.

Formula $C_{42}H_{25}O_{12}$, which is that of phloridzin + 2 equivs oxygen; but direct experiments with reducing agents have proved that it does not belong to the latter series

LINARITE. See CUPREOUS ANGLESITE.

LINCOLNITE. See HEULANDITE.

LINEA VULGARIS. Used as a yellow dye-stuff. Riegel's analysis of the flowers gave

Water.....	748.0
Fibre.....	135.5
Mucus.....	49.5
Sugar, with lime salt.....	32.0
Albumen.....	2.25
Tannin (greening iron).....	5.5
Fatty chlorophyll.....	8.0
Anthroxantin.....	11.5
Æthokirrin.....	—

Æthokirrin. The coloring matter of the plant is obtained by precipitating the hot aqueous solution of the alcoholic extract by lime-water, and treating the red deposit with acetic acid. The solution thus obtained is evaporated, the residue exhausted with alcohol, the extract precipitated with sugar of lead, the red precipitate decomposed by sulphuretted hydrogen, filtered, the solution evaporated, and the residue treated with ether. Purified with alcohol, it is then a pale yellow, verucose mass.

Prop. Tasteless, inodorous, sublimes unaltered. Dissolves with difficulty in water, more easily in alcohol and ether and the essential oils, less so in fat oils, forming yellow solutions. Soluble in caustic alkalies with a red color, except in ammonia, which with the carbonated alkalies gives a dark yellow. The addition of acids to these solutions produces a yellow precipitate. Neither iodide of potassium nor chromate of potassa precipitate the aqueous solution. *Chem. Gaz.* i. 509.

LININ. A light yellow, transparent sub-

stance, found by Paggenstechter in the *Linum catharticum*, or purging flax. Fuses between 239° and 249°. Soluble in alkalies, but decomposed thereby.

Prep. Exhaust the powdered plant with alcohol, precipitate by sugar of lead, add ammonia to the liquid, evaporate to dryness, and extract with rectified ether. The linin is left upon evaporation.

LINSEED. The seeds of the common flax, (*Linum usitatissimum*), consist of

Fat oil.....	11-265
Acrid soft resin.....	2-488
Wax	0-146
Resinous coloring matter	0-550
Yellow astringent extractive	1-917
Sweet extractive, with malic acid and salts	10-884
Gum.....	6-154
Nitrogenous mucilage, with acetic acid and salts.....	15-120
Starch, with salts.....	1-480
Albumen.....	2-782
Gluten.....	2-932
Husk.....	44-382

The ashes contain oxide of copper. (*Gmelin.*) Of the mucilage there is a soluble and insoluble portion. The former yields mucus and oxalic acids when treated with nitric acid.

Linseed Oil. Composition, 1 equiv. of margarate of glycerin and 10 equivs. linolein. (*Sacc.*) Is yellow, soluble in ether, and more readily in hot than cold alcohol. Spec. grav. 0-9347.

Prep. Obtained by pressure from the ground seeds either in the cold, or at a steam heat of 200°. Berzelius has styled the oleic acid of this oil, *linoleic acid*. It has the characteristic of being readily decomposable, and hence the necessity of excluding the access of air, and of using air-free ether, and an atmosphere of carbonic acid in its distillation. When exposed to a high heat it yields a viscous residue, which, when boiled in water, acidulated with nitric acid, becomes plastic and analogous in physical properties to caoutchouc. This compound swells and partially dissolves in ether, but is reprecipitated therefrom by alcohol. In pure spirits of turpentine it is wholly soluble. In general properties it resembles the ordinary oleic acid, but differs in composition, its formula being $C_{46}H_{98}O_5 + HO$ (?). As it forms the foundation of the extensive use of linseed oil in pigments and varnishes, further examinations might lead to important results.

Uses and Purifications. As the menstruum of pigments, the basis of varnishes and printers' inks. For the finer purposes of art it is purified and bleached by adding a solution of 2 lbs. of green vitriol in 3 quarts of pure water to 2 lbs. of raw linseed oil, and exposing the mixture to the sun for a month or more, until it has perfectly whitened and deposited all its mucilage. Frequent shaking during the interval facilitates the result. The vitriol solution by being filtered and evaporated to crystallization, is again fit for use. In the white lead works linseed oil is bleached by sulphuric acid. The residual portions left in by imperfect manipulation, have the good effect of neutralizing any hydrate which may be contained in the white lead with which it is ground, and thus

of preventing, in a measure, a yellowing by exposure or oxidation.

Another method of purification, especially for varnish use, is to rub up linseed oil with dry sulphate of lead in sufficient quantity to form a milky mixture. After a week's exposure to the light and frequent shaking, the mucus deposits with the lead, and leaves the oil perfectly clear. The oil, in time, will then become perfectly white. The precipitated mucus forms a compact membrane above the lead, and becomes so hard that the supernatant clarified oil may be poured off. The lead sediment freed of mucus is again fit for use. The varnish thus made is recommended for lac colors, as being cheap and preferable to those which contain either acetate or carbonate of lead.

LIPIC ACID. See **OLEIC ACID**.

LIPYL. A new radical, C_3H_2O , considered by Berzelius as the basic constituent of fats, and, like the base in the compound ethers, when set free from the fat acids as entering into a new combination with the elements of water, and forming **GLYCERIN**.

LIQUEFACTION. That abstraction of the heat of vapors and gases, which causes a reduction of their elasticity, and their condensation into a liquid state. A slight increase of pressure beyond the force of their own elasticity produces the same effect, provided there is no corresponding and simultaneous increase of heat to sustain it. All elastic bodies are not equally susceptible of liquefaction, for in some, air for instance, the repulsive force of the particles is so energetic, and the cohesive attraction so entirely overcome, that it has as yet been impossible, by any pressure, to condense them to liquids. The loss of sensible heat attendant upon liquefaction seems essential to the change, and suggested to Dr. Black his theory of latent **HEAT**. The term liquefaction is sometimes applied to the fusion of a solid.

LIROCONITE. *Min.* Prismatic Olivenite, Linsenerz. Cryst. Rhombic, prismatic. $H. = 2 - 2.5$. $G. = 2.88 - 2.98$. Sky-blue, verdigris-green; vitreous. It does not decrepitate, yields water, and becomes dark olive-green, yields on coal arsenical vapors and globules of copper in a semi-fused mass. Form. $(8 CuO, AsO_5 + 23 HO) + (2 Al_2O_3, AsO_5 + HO)$, in which the first member is **COPPER MICA**. It occurs in Cornwall.

LIRODENDRIN. Obtained by Emmet from the American poplar (*L. tulipifera*), or tulip tree.

Prep. Precipitates from the evaporated decoction of the bark. By treatment with slightly alkaline water, it is freed of resin and coloring matter, and being then dissolved in alcohol, and this solution rendered milky by water, drops, on cooling, in colorless plates or needly groups.

Prop. Slightly soluble in water, very soluble in alcohol and ether. Fuses at 180°, and volatilizes at 290° without alteration. It is neutral, and contains no nitrogen. Iodine yellows it. Concentrated nitric acid has no action, but the strong hydrochloric and sulphuric acids decompose it.

LITHARGE. See **LEAD**.

LITHEOSPORE. See **HEAVY SPAR**.

LITHIC ACID. See **URIC ACID**.

LITHIA MICA. *Min.* Lepidolite. Cryst. Rhombic in hexagonal prisms, and granular. $H. = 2.5$. $G. = 2.89 - 3$. Rose-red, gray; pearly; translucent; two axes of refraction. In a tube it yields water containing fluoric acid; it fuses readily and colors the flame red, especially if mixed with fluor-spar and bisulphate of potassa. Form. $RFl + 2R_2O_3, 3SiO_3$, in which $R = K, Na, L$, and $R_2O_3 = Al_2O_3, Fe_2O_3$.

Local. Zinnwald, Cornwall, &c.; Chesterfield and Goshen, Mass.; Paris, Maine.

LITHIUM. *Chem.* A metal discovered by Arfwedson, and existing in petalite, spodumene, lepidolite, and, as a carbonate, in some mineral waters. It is obtained by galvanic action from the hydrated oxide; and according to Davy is similar in properties to sodium, but owing to its rarity this analogy has not since been confirmed by fuller investigation. Equiv. 6.5.

Oxide. $LiO + HO$. Lithia is separated from powdered *Triphyllin*, the most abundant mineral containing it, by digestion to solution in hydrochloric acid and peroxidizing the iron with a little nitric acid. Dilute the liquid with water, and then add an excess of ammonia to precipitate the phosphoric acid and sesquioxide of iron. Through the ammoniacal solution pass sulphuretted hydrogen to separate magnesia, filter, evaporate to dryness, calcine the residue to expel ammoniacal salts, and dissolve the chloride of lithium in alcohol. Upon the addition of an excess of carbonate of ammonia, carbonate of lithia precipitates after a time, and must be collected on a filter, and washed with alcohol of 0.80 pr. ct. This carbonate, when finely powdered and boiled in a large quantity of water, becomes dissolved, and upon the addition of lime is decarbonated. The filtered solution, upon evaporation, yields hydrated oxide of lithia.

Prop. Nearly insoluble, unalterable on exposure; has a caustic taste and alkaline reaction, and attacks platinum.

Chloride. Crystallizes in cakes; very soluble in water and alcohol, and deliquescent on exposure.

Sulphuret. Soluble in water and alcohol, and eminently pyrophoric.

Sulphate. LiO, SO_3 . In crystals unalterable on exposure, fusible, soluble in water, and nearly insoluble in alcohol. It forms, with the sulphate of soda, a double salt, $(NaO, SO_3), (LiO, SO_3), 6HO$.

Nitrate. LiO, NO_5 . An anhydrous, deliquescent, crystalline powder, extremely fusible and soluble.

Carbonate. Slightly soluble in water, more so in water saturated with carbonic acid, insoluble in alcohol, and unalterable by heat.

Phosphates. The neutral salt, $2LiO, PO_5$, almost insoluble, and the biphosphate, LiO, PO_6 , very soluble in water, and crystallizable. The double salt of soda and lithia has the composition $2NaO, PO_5 + 2LiO, PO_5$, and is a white powder, soluble in 1400 pts. water at 59° , and in 950 pts. at 212° ; and entirely insoluble in liquids containing phosphates.

Oxalate. $2(C_2O_3, LiO)HO$. Neutral, crystallizable, soluble in water, unalterable on exposure, but decomposes when heated. The binoxalate, $C_2O_3, LiO + C_2O_3, 3HO$, is also crystallizable, but less soluble than the former.

The salts of lithia impart a red color to flame, and to distinguish it from strontia in this respect, Chapman heats the suspected substance in a microcosm of chloride of barium, which prevents chloride of strontium from tinging the flame. If, while at the point of the inner flame no redness is apparent, lithia is absent, and the red first obtained from the mineral, per se, is due to strontia.

LITHOFELLINIC ACID. Syn. Lithofellic. Exists as the predominant constituent of Bezozars, and is extracted by hot alcohol from its solution, in which it drops on cooling, and can be purified by recrystallization.

Prop. When pure is in small, colorless, 6-sided prisms. Sparingly soluble in ether, and insoluble in water. Alcohol dissolves it slowly, and acquires an acid reaction. Fuses at 401° , and congeals into a vitreous mass, whose melting point is then 220° to 230° , or 180° lower than that of the crystallized.

A saturated solution of the lithofellinic acid of potassa gives white precipitates with the neutral salts of silver and lead; the compound with the former, however, dissolves duringedulcoration. The crystallized silver salt is obtained differently:—By mixing an alcoholic solution of the acid with nitrate of silver and some ammonia, warming the solution to dissolve the precipitate, and evaporating. Concentrated sulphuric and acetic acids dissolve it. The former solution is rendered turbid by water. From the latter it crystallizes on evaporation.

Wöhler's formula for the crystallized acid is $C_{40}H_{35}O_7 + Aq$; and though differing from Ettling and Wills ($C_{42}H_{37}O_7 + Aq$), is most probably correct, because agreeing in the number of equivalents of carbon with that of the crystallized resin, with which, in all its properties, lithofellinic acid is identical.

Malaguti and Sarzeau, by the action of nitric acid, obtained lithagofellinic acid, $C_{40}H_{25}O_{14} + 2(NO_3)$, and by dry distillation pyrolithofellinic acid, $C_{40}H_{34}O_6$. For an interesting paper upon the mutual relations between this acid and the sulphur of the oxbile, see *Chem. Gaz.* iv. 471.

LITHOMARGE. *Geol.* A compact, clayey mass, due to the decomposition of various mineral substances.

LITMUS. See LICHENS.

LIVER. The organ of the body which secretes bile. Boudet gives the following comparative composition of a healthy and morbid liver:—

	Healthy.	Morbid.
Neutral fat, with a little fat acid	1.60	30.20
Cholesterin	0.17	1.33
Extract soluble in ether	0.84	—
Solid, insoluble tissue	21.00	13.32
Water	76.39	55.15

Bernard and Barreswill, (*Comptes Rendus* xxvii., p. 514.)

Sugar, also, is a constituent of the tissues.

LIVER OF ANTIMONY. See ANTIMON, p. 232.

LIVER OF SULPHUR. The tersulphuret of potassium $= K, S_3$.

LIXIVIATION. The separation of the saline, soluble portions of permeable bodies, by infiltration with water. The term is most generally applied to the leeching of ashes and alka-

line materials, and the process is based upon the same principles and practice as is that of DISPLACEMENT. EDULCORATION and the washing of precipitates in ANALYSIS are kindred operations.

LIXIVIUM. The old term for the saline solutions obtained by lixiviation.

LOAM. *Agric.* It is a soil consisting of a due admixture of sand and clay. The moderate cohesion of its particles renders it a valuable medium for the entrance of the air to the roots of plants, and for the supply of moisture to vegetation. As clay or sand is the predominant ingredient, loam is friable or mellow, middling or heavy.

LOBELIA INFLATA. Reish's analysis of the herb gave—

	Water	0-110
	Essential oil.....	undeterminable
Alcoholic Extract.	{ Chlorophyll, wax, resin, }	0-055
	and stearin.....	
	Lobelin	0-022
	Aromatic resin	0-013
	Vegetable gelatin.....	0-028
Aqueous Extract.	{ Mucus gum.....	0-060
	Salts of potassa, lime, mag-	
	nesia, iron, and manga-	
	nese, with organic and	0-024
	inorganic acids.....	
Extract with Potassa.	{ Mucus gum	0-424
	Vegetable fibre	0-266

Lobelin. Prepared by treating the spirituous extract, exhausted by ether, with alcohol of 0-819, evaporating the solution, and extracting the residue with water. The brownish acid solution, on evaporation, yields lobelin, which when dry is a shining, gummy substance, easily soluble in water and alcohol, but not in ether. Its aqueous solution is not affected by the acids, and is only darkened by ammonia. Tincture of galls throws down a voluminous white precipitate.

Vegetable gelatin is the soluble portion of the spirituous extract, insoluble in alcohol. The so-called *mucus gum*, unlike the lobelin, is not colored by iodine, does not form a gelatinous mass with alcohol or acids, nor does it give pectic acid or humin by boiling with alkalis, but is precipitated as a shining mass.

The lobelin which Calhoun found in this herb, forms salts with the acids. The acid properties of a decoction of the plant, he ascribed to *lobelic acid*.

LOBOITE. See **INOCRASE.**

LOGWOOD. The wood of the *Hæmatoxylon Campechianum*. Consists of volatile oil, hematic, (*Hæmatoxilin*), fatty or resinous, astringent and glutinous matters, acetic acid, woody fibre, silica, salts of lime, potassa, alumina, manganese, and iron.

Its principal use is as a dye-stuff; and for convenience of transportation the coloring matter is separated by water at steam-heat, evaporated to, and sold under the form of, Extract.

LOTALITE. See **HORNLENDE.**

LUNAR CAUSTIC. Nitrate of **SILVER.**

LUPULIN. See **HOPS.**

LUSTRE. *Ger. Glanz.* The peculiar kind and amount of light reflected from the surface

of minerals. The kind of lustre is *metallic*, that of the metals, as galena, pyrites; *vitreous*, that of broken glass, as crystallized quartz, topaz; *resinous*, like common rosin, as blende; *pearly*, as talc, lepidolite; *silky*, a pearly lustre when the specimen is fibrous, as gypsum; *adamantine*, that of the diamond. The amount of lustre is *splendent*, when a surface reflects a perfect image, as specular iron; *shining*, when the image is not well defined; *glistening*, when no image is reflected, as talc; *glimmering*, when there is very little reflection of light; and *dull*, when there is none, as clay. Among silicates a cleavage face is often pearly, and another surface vitreous.

LUTE. Adhesive mixtures of earthy or other materials for closing joints of apparatus, so as to prevent the escape of vapors. They are plastic when moist, and in this state are applied; but they soon harden and become impermeable to moisture or gases.

Flaxseed meal and whiting, softened with water, make an excellent lute for vessels used for the distillation of spirits. For the more penetrating and corrosive liquids, such as ammonia, &c., caustic lime made into a thick paste with glue, must be used, and then covered over with strips of glued cotton. For subliming pots, a compost of ground pipeclay, sal enixum, and water is preferable. *Fat lute*, which will stand elevated temperatures, is made by beating powdered dry pipe-clay with linseed oil, until it becomes soft and ductile. As it softens by heat, it must be confined by strips of bladder.

Plaster of Paris, made into a paste with water, is a very good lute for ordinary purposes.

Iron cement, prepared by moistening 1 pt. of sulphur, 2 of salammoniac, and 80 of iron filings, with water, is used for making permanent joints between surfaces of iron. This must be mixed only in quantity, as wanted.

The application of these lutes to the joints, is much in the same manner as the glazier glazes a window with putty.

In analytic and the nicer chemical operations, the juncture of glass tubes is closed and connected by strips of sheet caoutchouc. See Morfit's "*Chemical and Pharmaceutical Manipulations*."

LUTEOLIN. See **WOAD.**

LYCOPODIUM. *Chem. Tech.* Syn. Witch-meal, Vegetable sulphur. The small, pale, yellow, dusty particles contained in the capsules of the *L. clavatum* or common *Club-moss*. Used in medicine for enveloping pills, and in pyrotechny to represent a flash of lightning.

LYDIAN STONE. See **QUARTZ.**

LYMPH. The liquid portion of BLOOD devoid of its coloring matter, and may be considered as a dilute serum. It is yellow and sometimes opalescent; coagulates in 10 or 15 minutes into a clear, tremulous, yellow jelly, and deposits an arachnoidal coagulum of fibrin. The residual fluid is rather thick and oily, and under the microscope exhibits a corpuscular structure. (*Müller.*) Geiger's analysis gives—

Water	983.7
Extractive matter	2.7
Fibrin	0.4
Albumen	6.2
Chloride of sodium, phosphates of potassa and soda, and salinary matter.....	7.0
Fat and ammoniacal salts.....	traces

The per centage of water varies from $92\frac{1}{2}$ to 98 pr. ct. The amount of fibrin and albumen differs according to the animal whence the lymph is taken, and the state of its health. Among the solid constituents, the proportion of which is also variable, some chemists have found fat in the form of oleate of soda. For several other analyses, see *Simon's Chemistry*, p. 289.

M.

MACE. See MYRISTICA.

MACERATION. The extraction of the soluble portions of a substance, by steeping in a menstruum at the ordinary temperatures of the atmosphere. DISPLACEMENT with a cold liquid would be a more effectual and economical process.

MACLURITE. See CHONDRODITE.

MADDER. The root of the *Rubia tinctorum*. *Levant, Turkey, or Smyrna* madder is imported in the whole root. Dutch or Zealand madder is imported ground. Four kinds of the powder are distinguished:—*crop* (the best), *ombro*, *gamene*, and *mull* (the worst). *French madder* is imported both ground and whole; it is produced in the environs of Avignon and Alsace. *Pereira*.

The nature of the coloring matters of this dye-stuff was investigated in 1843 by Girardin, who reports his results in the *Journ. de Pharm.* for that year.

Garancin. A more or less clear chocolate-colored powder, which does not impart any color to the saliva or to cold water, even by long contact. This garancin is the *charbon sulphurique* of MM. Robiquet and Colin, deprived of every trace of acid. A patent was taken out on the 26th of March, 1828, by MM. Lagier, merchant, and Robiquet and Colin, professors of chemistry, for the manufacture and sale of this new product.

"The problem to be solved," say the patentees, "is to obtain the whole of the coloring matter of the madder free from the foreign bodies which tarnish its lustre, and retain it in combinations different from those which it ought to contract with the mordants; now the madder in its natural state contains coloring matter in various conditions. Thus, in the dyer's bath it separates into two portions, one of which is either dissolved or suspended in the water, whilst the other remains fixed in the ligneous residue. In treating the exhausted residue, which is generally considered worthless, by the method described below, a quantity of coloring matter, at least equal to that first extracted from it, is obtained. Besides, the portion which the water carries with it, either in solution or in suspension, is far from being attracted by the mordant of the stuffs immersed in it. A great part remains in the bath, in combination with some substances which retain it with sufficient energy to prevent it from combining with the mordants beyond a certain limit."

The following is the process proposed by them:—"The madder is immersed in from 5 to 6 pts. of cold water, and allowed to macerate all night, in order that the portion of the coloring substance which dissolves at first may

have time to subside; the whole is then thrown upon linen strainers, and when the liquid has passed through, the grounds are pressed; they are then immersed again in the same quantity of water, pressed, and this operation repeated once more. After these three washings, which serve to remove a green substance, besides sugar, mucilage, and other soluble substances, the grounds, still moist and well crushed, are mixed with sulphuric acid equal to half the amount of madder first employed; it is, however, requisite that this acid should be diluted more or less with water, according to the temperature; this is done when it is about to be employed, in order to turn to account the heat set free by the mixture. The acid thus diluted is poured quite hot over the madder; it is then agitated as rapidly as possible, and when the mixture is thought to be well effected, the temperature is raised to 212° Fahr., and maintained for about an hour. At the end of this time the substance is again mixed with a suitable quantity of water, filtered, and washed on the strainers until the liquid passes off perfectly insipid; it is then pressed, dried, and passed through the sieve.

"In this operation the acid has undergone no alteration; it has merely become weaker and charged with some calcareous salts, which do not prevent its being employed in the manufacture of sulphate of soda. The first washing-water might also be turned to account, since it contains much sugar, which might easily be converted into alcohol."

M. Schlumberger-Rouff manufactured the garancin which he used according to the following process:—"After having ground the already pulverized madder on a table, by means of a thick wooden rolling-pin (such as is used by pastry cooks), it was placed in a leaden basin, then moistened with a little water, and half its weight of sulphuric acid of 1.834 spec. grav. poured over it, whilst two men continually stirred the mass with shovels, walking around the basin. When the charring (*brûlage*) was ended it was washed five or six times in barrels, the product drained upon linen, and then dried in a chamber heated by steam. It was afterwards ground in a water-mill made upon the plan of pepper or coffee-mills. This garancin was very acid, and could not be used for violet colors."

The following is the behavior of garancin towards solvents:—

Cold distilled water.—After 24 hours of contact it has only assumed a pale, yellowish color.

Distilled boiling water.—Acquires a pale, reddish yellow tint.

Cold calcareous water.—After 24 hours it is less colored than with cold distilled water.

Boiling calcareous water.—A somewhat paler tint than with distilled boiling water.

Cold lime water.—After 24 hours the tint is paler than that with distilled boiling water, and than that with boiling calcareous water.

Water acidulated with sulphuric acid.—Takes, after some hours, a slightly greenish yellow tint.

Water acidulated with hydrochloric acid.—Takes, after some hours, a rather darker tint.

Cold distilled water, acidulated with nitric acid.—Takes, after some hours, a rather darker

tint, and the blackish gray powder becomes of a brownish red, resembling madder become brown by age.

Cold distilled water, acidulated with acetic acid.—Becomes faintly yellow.

Acetic acid of 1.0704 spec. grav.—Acquires, after several hours, a beautiful reddish yellow color.

Caustic ammonia.—Becomes red immediately, and after 24 hours the liquor is strongly colored crimson-red, so intense that it is no longer transparent in a great mass.

Water slightly alkalinized by ammonia.—Immediately assumes a beautiful claret-red color.

Caustic soda.—A dark, reddish brown color.

Water charged with carbonate of soda.—Acquires quickly a bright reddish color, of Burgundy wine.

Cold alum water.—Becomes almost immediately of a chrome-red color.

Boiling alum water.—Acquires immediately a dark red color, and upon cooling deposits flakes of the same color, but paler.

Alcohol of spec. grav. 0.863, and Hydrated ether.—Assumes rather quickly a slight reddish yellow color.

Dyeing with garancin is effected in just the same manner as with madder. It is more advantageous, however, to raise the bath at once to 113° Fahr., and then gradually to 167° or 176°. Garancin only yields its color to the tissue impregnated with the mordant at a boiling temperature. The water of the bath acquires no color even after ebullition, which always terminates the dyeing with garancin.

The mordants are the same as those which are employed for dyeing with madder.

certain colors in which there is no violet, sumach is sometimes added to the bath, to the amount of about a third of the garancin employed. At other times, for red grounds for instance, the pieces are quercitronned before garancing, which imparts much brightness to the red, but renders the violet gray.

The proportion of garancin used in dyeing calico prints varies considerably, according to the intensity of the tints and the quantity of color required by the pattern.

When the garancins are neuter and the waters are calcareous, they must be corrected by adding a variable proportion of sulphuric, acetic, or oxalic acid to the bath. 1 centilitre of sulphuric acid of 1.028 to 9 litres of water, or 15 centigrammes of oxalic acid to a litre of water, are about the quantities employed. When sumach is added, no acid is employed.

There are some garancins which are badly washed, and acid, and to which it is therefore necessary to add chalk or alkaline carbonates, in order to get rid of the too great excess of acid, which would be injurious; but chalk and alkalies are avoided as much as possible.

The great advantage of garancin is, that it does not charge the white, and that the bleaching of the stuffs dyed with garancin is reduced to a mere nothing. When a very pure white is not required, it suffices merely to beat and sufficiently clear the pieces after the garancing. When a perfect white is required, the pieces are passed through bran for 15 or 20 minutes. Hot water or bran are the only means used for clearing them. In this respect, therefore, ga-

rancin possesses a great advantage over madder, which covers all the whites, and which renders it necessary to use soap, and to clear them more or less after the process of dyeing.

The tints obtained with garancin are generally more brilliant and lively than those with madder. The red is vivid, of a carmine color of extraordinary purity, whilst the madder red, placed by its side, is always somewhat yellow, or of a fawn color, and dull, but on the other hand fuller. The puce and garnets made with garancin are much more velvety than those dyed with madder. The violets are not so pale and delicate and gray as with the latter. All the tints are weaker, and cannot so well bear soaping; they also require great care in the clearing, and resist less the action of the atmosphere and of the sun.

All the garancins, however, do not afford tints of equal richness and brilliancy. Some kinds produce a beautiful red, but a bad violet color; other kinds afford a magnificent puce or violet, while the red is dull brown.

Testing of the Garancins.—The quality of the garancins varies. The testing of them is on a large and on a small scale. In the latter case samples are taken, taking care to cork the labelled bottles in which they are enclosed as quickly as possible, in order that they may not dry, which in summer time especially causes an amelioration of from 5 to 6 pr. ct. in a few days, on account of the water which evaporates.

A piece of calico, printed in stripes of red, violet, puce, and garnet is taken (black is useless, as all the garancins produce that well), not gummed as usual, and dried. As many decimetres are cut from it as there are garancins to be tried, and the pieces are marked by notching them with the scissors: the notches must correspond with the numbers on the bottles.

From 1.9 grm. to 2 grms. of garancin, known to be good, is weighed off to serve as standard, and for the garancins to be tried we take 1, 2, 3, 4, 5, 6, 7, 8, 10 times more or less of 1.90 or 2 grms., according as they cost 1, 2, 3, 4, &c., more or less than the standard sample. As the samples are weighed, they are each put into a jug with a wide mouth, holding half a litre, with from 2 to 2½ decilitres of water, containing some oxalic acid in the proportion of 15 centigrms. to a litre. The jugs are numbered, so as to correspond with the samples of the garancins and strips of calico. They are placed in a water-bath, in a copper boiler with a flat bottom, the pieces of printed calico are immersed in them, and dyed as in testing the madders, regulating the fire so as to raise the temperature to 158° in an hour and a half, and keeping it at the boiling point for half an hour. After the process of dyeing, the samples are removed as quickly as possible from the vessels, rinsed in water and beaten, and then dried, or previously immersed for 5 or 6 minutes in a bran-bath at 167°. When dry they are compared, and in this manner the relative tinctorial value of the garancins may be estimated as nearly as possible.

In employing calicoes which present at the same time stripes mordanted for red, violet, puce, and garnet, it is seen at once whether the garancins can be employed with advantage

for all colors, or for what tints they are most suited. The same garancin does not always suit equally well for red, puce, and violet. *Girardin. (Chem. Gaz. ii.)*

Colorin. (Alcoholic extract of charbon sulphurique. Robiquet and Colin.) The residue from the distillation of the alcoholic liquid, obtained in the treatment of the charbon sulphurique with spirits of wine. The residue, which consists of alizarin still impurified, with a little fatty matter, is in the form of an extract when withdrawn from the retort. It is diluted with a little water and pressed, in order to separate the fatty matter from it as much as possible. When dry and reduced to powder, it is of a yellow-ochre color, without any decided smell or taste; moistened it stains the fingers strongly of a yellow color, but it hardly colors saliva. It presents all the chemical characters which Robiquet and Colin assigned to their alizarin.

Colorin dissolved in ammonia and the liquor thickened with gum, affords, when printed on calicoes with aluminous mordants and exposed to steam, red and rose colors, which are by no means inferior to those obtained with madder dyes. *Girardin.*

The later examinations of other chemists have presented the composition of madder differently from the foregoing, and it is now declared that the root contains four coloring principles, viz.: a pale red, a yellow (the *xanthin* of Kuhlman), an orange (the *alizarin* of Robiquet and Colin), and a purple matter (the *purpurin* of Claubry and Persoz). According to Decaisne, however, madder contains but one coloring matter, and that is a yellow, which passes into the different shades of red by the absorption of oxygen.

Xanthin. Amorphous and yellow, readily soluble in water and alcohol, but insoluble in ether. Alkalies color it orange-red, and the acids lemon-yellow. Is not precipitated from its solutions by the metallic oxides, but is separated in an impure state from the alcoholic extract of madder, by water.

Alizarin. $C_{30}H_{16}O_8$. *Prep.* By treating the *Charbon sulphurique*, before mentioned, with boiling alcohol, adding water, distilling the mixture, separating the alizarin from the aqueous residue by filtration. By sublimation and washing with ether, orange crystals are obtained.

Prop. Soluble in alcohol, with red color; less so in ether, and with a yellow tint; much more soluble in hot than in cold water, the former precipitating it in flocculæ from its solution in concentrated sulphuric acid. This substance is identical in composition and properties with the *Lizarinic acid*, recently extracted from madder by Debus, along with oxylicannic acid. Its salts are red or violet, and excepting those of potassa, soda, and ammonia, insoluble in water and in alcohol. (*Ann. der Chem. und Pharm.* lxi., p. 351.)

Purpurin. Fusible and volatile. Resembles the preceding, but is of a deeper color, and differs from it in being readily soluble in a boiling alum solution. It is thus extracted from *garancin*, and is then precipitated by sulphuric acid. Is less soluble in water than alizarin, and very slightly soluble in ether.

The opinion has been broached that the various pigments contained in the root of the madder, are probably oxides of one and the same radical. No actual investigation, in support of this view, exists. Robiquet's analysis has been rendered perfectly valueless by the investigations of Runge, who proved that several volatile pigments are contained in the madder. The highly valuable microscopic examination of Decaisne showed that the red pigments are not perceptible in the fresh root.

The greatest difficulty which is met with in examining the madder pigments, is the separating of them from one another. After numerous experiments, the following process was found most advantageous. The ground madder root was treated with water in a wooden vat, and left undisturbed for one or two days, the water poured off, and the madder, after being pressed, repeatedly extracted with a boiling concentrated solution of alum in a copper boiler. The filtered decoction deposits, on cooling, a reddish brown substance, which may be separated by filtration. When the clear red liquid thus obtained is mixed with sulphuric acid, the dissolved pigment generally separates in the course of 24 hours, and the liquid is then but very faintly colored; the pigment is collected on a filter, and dissolved in a boiling solution of alum. If a fresh deposit is formed on cooling, it is separated by filtration, and the liquid again treated with sulphuric acid. The precipitate thus obtained is washed with dilute boiling muriatic acid, and afterwards with cold water, and dissolved in alcohol, the greater portion of the alcohol distilled off, and then left to spontaneous evaporation. The madder-purple which is deposited is dissolved repeatedly in ether, about two-thirds of the ether each time removed by distillation, and the remainder allowed to evaporate, when the pigment gradually separates.

The madder-purple obtained in this manner forms a brilliant cherry-red powder, which is scarcely soluble in cold water, tolerably so in boiling, and very readily soluble in alcohol and ether. It dissolves in alkalies of a dark red color, from which it is precipitated by acids in red flakes. When heated, it melts and is volatilized, apparently, however, undergoing some change. If the sealed end of a glass tube, about 2½ inches long and some lines in diameter, is blown out into a bulb, a small quantity of the purple conveyed into the bulb, and this immersed, together with a thermometer, in a platinum crucible of moderate size, half-filled with oil, and heat applied; the portion of the tube projecting out of the oil becomes coated at 437°, with a violet film; and if the temperature is raised, this portion of the tube is gradually filled with minute crystals of the pigment. This property of madder-purple is opposed to the statement of Runge, according to whom the sublimed madder-purple is not crystalline. On filling a small platinum crucible of about 3 centimetres in height one-fourth full with madder-purple, placing a small funnel stopped with some paper over the crucible, and cautiously heating over the lamp, in a sand-bath, a quantity of the most beautiful crystals, of a cherry-red color, are obtained. These crystals, however, no longer yielded with pot-

ash a red, but a violet solution; the residuary portion in the crucible affords, when it has not been heated too strongly, the same violet color with potash. Madder-purple yielded, on analysis, $C_{28}H_{10}O_{15}$.

The behavior of the madder pigments towards concentrated sulphuric acid is of vast importance in the manufacture of garancin. When madder-purple or madder-red, or a mixture of the two is dissolved in cold, concentrated sulphuric acid, the solution is of a splendid cherry-red color; if to this solution from one-fourth to one-third of its volume of water be added, the coloring matter separates unaltered from the hot liquid. If the solution of the pigments in concentrated sulphuric acid is heated to 230° , the pigments are not altered even at this temperature; they separate unchanged when the still hot solution is cautiously poured into a vessel containing water. If, in the preparation of garancin, the sulphuric acid is diluted with from one-fourth to one-third of its volume of water, there is no reason to fear any considerable quantity of the pigment being dissolved in it; nevertheless an acid of this strength immediately blackens a shaving immersed in it. The employment of too concentrated an acid has, judging from this behavior, the disadvantage that the flakes of pigment which separate on dilution are readily carried away by the wash-water. From the above experiments, moreover, it is evident that there is no need for so much anxiety respecting the temperature in the preparation of garancin, as many directions given in chemical works would make it appear.

Sublimed Madder-purple. Forms beautiful crystals, but its behavior towards alkalis shows that the madder-purple experiences some change during the sublimation, which is also confirmed by analysis; for it yielded—

Carbon.....	53.30
Hydrogen.....	5.19
Oxygen.....	40.51

What this change is, has not been determined, except so far as regards the generation of carbonic acid.

According to the statement of Robiquet and Colin, the crystals of alizarin are accompanied by a fatty substance, which prevents their dissolving in water; this substance is said to be removed by moistening with alcohol, and the alizarin rendered soluble. The assumption of a fatty substance is undoubtedly founded upon some error. If sublimed or unsublimed madder-purple or madder-red is moistened with a few drops of alcohol, the pigment, which alone is not soluble in water, passes with the alcohol on mixing with water, into solution; the same happens when they are just moistened with ether, in order to remove the supposed fatty substance. The crystals of the sublimed madder-purple dissolve with difficulty in a boiling solution of alum; their solubility is increased by reducing them to powder.

Madder-red. This substance is contained in the precipitate which subsides from the hot decoction on cooling; if this deposit be boiled with alcohol to which a concentrated solution of alum has been added, there is obtained on cooling two strata of pigments; the upper

bright red, flocculent layer is removed with a pipette, and some of the above mixture of alcohol and solution of alum poured upon the lower dark-brown deposit, which is then heated, and again treated as above. When the flakes of the upper layer produce a pure violet solution with potash, the brown sediment is washed after their removal with dilute, boiling muriatic acid, and afterwards with water, dried, and treated with boiling alcohol, which dissolves the madder-red, leaving behind a brown substance. The alcohol is distilled off, the pigment dissolved in ether, a portion of the ether removed by distillation, the solution then left to spontaneous evaporation; and, when the greater portion of the pigment has separated, the remainder poured off. The treatment with ether is repeated until a powder of a pure brilliant yellow color is obtained.

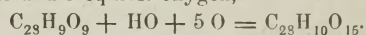
Madder-red is very sparingly soluble in water, but readily so in alcohol and in ether; with potash it yields a violet solution; ammonia and the fixed alkaline carbonates dissolve it with a red color. It behaves, when heated, quite analogous to madder-purple; at 437° it begins to volatilize, and is deposited in beautiful orange-yellow needles. An attempt to reduce both madder-red and madder-purple, according to Preisser's method, has not been successful. A small quantity of madder-red submitted to analysis, yielded the following results:— $C_{28}H_9O_9$.

The formula $C_{28}H_9O_9$, as well as the preceding ones, must only be regarded as convenient expressions of the analytical results.

Sublimed Madder-red. The behavior of this substance agrees with that of the unsublimed pigment; the crystals are not soluble in water, but dissolve with ease in ether and alcohol. It is probable that its composition does not differ, although the analysis yielded a somewhat different result, viz.—

Carbon.....	67.71
Hydrogen.....	4.51
Oxygen.....	27.78

It appears to result, from the preceding observations, that madder-red may pass into madder-purple by the assimilation of 1 equiv. water and 5 equivs. oxygen,



If we adopt the formula $C_{28}H_{16}O_{16}$ instead of $C_7H_4O_4$, the sublimed purple differs from the red pigment only in containing 7 more equivs. of water.

In some experiments which Shiel made with a view of ascertaining the action of oxygen upon these pigments, madder-purple did not absorb half a cubic centimetre of the gas during 48 hours' confinement in a tube filled with oxygen, and remained unaltered; madder-red appeared to become converted into the purple pigment, for in attempting to close with the blowpipe the apparatus containing the madder-red, an explosion resulted, and the substance was scattered in all directions; at several parts of the tube there were dark, circular spots; and what was collected of the substance was of a brown color, and no longer yielded with potash a violet, but a red solution. (*Liebig's Annalen*, October, 1846.)

Madder lake. Inglefield's process is to enclose the best crop madder in a bag, and beat it well in successive portions of water until it ceases to give color. The mixed liquors are then boiled in an enamelled vessel, and treated with 1 oz. of alum (dissolved in 1 pt. hot water) to every 2 oz. madder. Stir well, and during the agitation gradually add 1½ oz. saturated solution of salt of tartar. When it has cooled and settled, decant the supernatant yellow liquor, agitate the residue with boiling water, decant, drain, and dry. The yield is about 25 pr. ct. Ure's method, which differs but slightly from this, is given in his *Dictionary of Arts and Manufactures*.

Adulterations. The high price of madder, and the facility of adulterating it with foreign pulverulent matters, subjects the powdered root to a number of sophistications. There are two kinds of adulteration:—Earthy or mineral substances, and sometimes vegetable substances, the color of which resembles that of madder.

1. *Adulteration by Mineral substances.* The mineral substances are brick-dust, red and yellow ochre, yellowish sand, yellowish clay or argillaceous earth. A madder which contains earthy substances grates between the teeth when chewed.

A small quantity of such a madder, for example from 25 to 30 grms., introduced into a large glass globe and diluted with 5 or 6 litres of water, quickly deposits the greater portion of the earthy substances at the bottom of the vessel. When the suspended madder is decanted and the deposit agitated with a fresh quantity of water, the earthy substances are isolated, and may be examined. However, to determine the proportion, more exact processes must be had recourse to. The best is that of calcining, at a red heat, in a platinum crucible. 5 grms. of the madder under examination are first dried completely at 212° Fahr., and are weighed with great exactness, and then put into the platinum crucible, which must be weighed beforehand. The crucible is shut,

and heat gradually applied. When perfectly incinerated the crucible is taken out of the furnace, and left to cool, and then weighed; its weight being deducted from the quantity employed, the difference gives the proportion of cinders obtained.

These cinders are composed,—1st, of the fixed mineral matters contained in the root, and 2d, of the earthy substances foreign to the chemical constitution of the root, and which have been accidentally or fraudulently mixed with the madder.

Madder which is very pure, and quite free from its epidermis, or any foreign earthy matter, and dried with care, gives by incineration 5 pr. ct. of ash; that of the Lizaris of Provence, stripped of its pellicle, gives on an average 8-80 pr. ct. ash.

According to M. Henri Schlumberger, 100 pts. of Alsatian Lizaris washed in distilled water and dried at 212°, give 7-20 pr. ct. of ash, whilst 100 pts. of Lizaris of Avignon, prepared in the same way, give 8-766.

According to M. Chevreul, 100 pts. of Lizaris from the Levant, dried at 212°, give 9-80 ash.

When an Avignon madder, SFF (the mark most generally used), subjected to the test of incineration, gives a greater weight of ash than 5 pr. ct., which is the mean of numerous experiments, the excess must be attributed to the presence of foreign earthy or sandy matters, either arising from adulteration or a careless preparation of the powder.

When the excess is only from three to four-hundredths, it is probably owing to some fault in the preparation of the madder, the manufacturer not having separated the epidermis (which is always coated with the earth which surrounds the root) carefully enough by grinding; but when the excess is above 4 or 5 pr. ct., or more, it is the result of fraud.

The madders obtained from the merchants give very variable results with respect to the proportion of ash which they furnish, as the following table shows:—

	Per cent. of Ash.
On 6 trials the mulle madder of Avignon gave.....	4-00
On 7 trials the madder SF of Avignon gave from.....	12-40 to 20-00
On 18 trials the madder SFF of Avignon gave from	7-40 to 23-00
On 4 trials the madder SFFP of Avignon gave from.....	12-00 to 16-00
On 3 trials the madder SFFP of Avignon gave from	10-00 to 10-80
On 7 trials the madder EXTf of Avignon gave.....	10-00

When, in testing a madder by incineration, the quantity operated on amounts to 5 grms., the weight of the ash must be multiplied by 20, in order to bring it to 100 pts., and from the figure obtained, 7 pts., representing the mean weight of ash pr. ct. furnished by good madder, subtracted; the surplus then represents the proportion of earthy matters or of sand added by the manufacturer. Consequently, a madder furnishing 16-40 pr. ct. of ash, will contain 9-40 pr. ct. of foreign matter.

2. *Adulteration by Vegetable substances.* The vegetable substances introduced into the madders are powders of little or no value, such as sawdust, almond-shells, bran, the bark of the so-called pine-tree, mahogany wood, logwood, sandal wood, and fir-tree wood.

The sophistication of madders by these dif-

ferent substances is much more prejudicial to the dyer than that by mineral substances; for besides diminishing, like the latter, the quantity of coloring matter of a given weight of madder, they also injure the dye, either by absorbing the coloring matter, or by preventing the colors becoming so bright.

It is extremely difficult to ascertain with what kind of vegetable substance a madder has been adulterated; it is mostly only possible to ascertain that there is a mixture. This, however, is the most important point, and the practical man, after all, only needs to know the tinctorial worth of the madder which he buys.

Determination of Coloring power. One method is to test the coloring power by means of Labillardière's colorimeter. The second, in determining this coloring power, as well as the

solidity and brilliancy of the colors, by an operation of dyeing. The third experiment is to ascertain the absolute quantity of the coloring principle. These different experiments are always made comparatively, by taking for type a madder prepared with all possible care, and having the same marks as that under examination. As with indigo and other tinctorial substances, a single experiment is not sufficient; and by reason of the difficulty there is of correctly verifying the value or the quality of the madders, it is indispensable, in order to decide with any certainty, to check the experiments by each other. This is the only way of obtaining satisfactory results.

1. *Determination of the Coloring power by the Colorimeter.* The following is the mode of operation with the colorimeter of Labillardière:—The type madder and the madder under examination are dried at 262° Fahr., and an account is kept of the respective quantities of hygrometric water they contain. 25 grms. of each sample are then mixed with 250 grms. of water at 68°. After 3 hours of contact the whole is thrown upon a linen cloth. A second maceration is made with the same amount of water, and for the same length of time. The madders are then washed with 250 grms. of cold water, dried at 212°, and weighed, in order to ascertain the proportions of soluble, saccharine, and mucilaginous matters which they have lost by these preliminary washings, which only remove an insignificant quantity of red coloring matter. 5 grms. of each of the two madders are then introduced into little glass globes with 40 pts. of water and 6 pts. of very pure alum, boiled for a quarter of an hour, and the boiling liquids filtered. The grounds are washed with 2 pts. of hot water. Two other decoctions, similar to the first, are made, and each time the residue is washed with 2 pts. of hot water. The products of the three decoctions are combined, and the liquids from the two samples of madder compared by the colorimeter.

Without doubt this examination with the colorimeter is not sufficiently accurate, but it affords valuable indications, which, joined to those resulting from the following tests, enable us to give a decided opinion.

2. *Determination of the Tinctorial power by Dyeing.* In order to estimate the value of a madder by dyeing, a madder of superior quality must be taken, as a type of comparison, with which skeins or mordanted calicoes have been already dyed, by acting with determinate quantities of powder, tissue, and water.

Whatever vegetable powders may have been fraudulently introduced into the madders, whether tinctorial or inert, they can never lead to error as to the true tinctorial value of the mixture, inasmuch as the colors which they afford, and which saturate the mordants at the same time as the red principle of the madder, cannot withstand the action of the clearings as the later does; they *run*, as is said in the soap and tin-baths, and in the end there only remains the color from the madder, upon the tissue. The clearings are therefore necessary to show the solidity and vivacity of the tints obtained.

3. *Determination of the Quantity of the Coloring principle.* The most exact process hitherto

published, is without doubt that made known by M. H. Schlumberger, in 1838, as modified by M. Scheurer. But this process, which is founded on the solubility of the red coloring principle of the madder in weak acetic acid, a fact pointed out as early as 1829 by an anonymous chemist, is unfortunately too sensitive, and requires too great a degree of skill in the manipulation to become general.

The following is the method:—50 grms. of madder are diluted with 50 grms. of concentrated sulphuric acid. The whole is left in contact for some hours; too high a temperature should be avoided. The charcoal obtained is mixed with water and thrown upon a filter; it is then washed until the water passes through quite insipid, and next dried at a temperature of 212°. This charcoal is reduced to a fine powder, and macerated for two hours at three distinct intervals, with cold alcohol containing a little ether, in order to free it from a fatty matter which it retains. The powder is boiled in alcohol of 0.834, at three different intervals, employing each time about 250 grms. of alcohol. When this is no longer colored by ebullition, the alcoholic liquors are mixed, and distilled in a small glass retort to the consistence of a syrup, and the concentration of the liquid completed in the water-bath in a weighed, porcelain crucible. When the extract is perfectly dry, its weight is taken. This represents the proportion of red tinctorial principle contained in the madder.

This process is rather long; it does not give, especially on a small scale, the absolute proportion of coloring principle contained in the madder; there is a slight loss, but by acting comparatively, a sufficient approximation is obtained.

Such are the different methods for ascertaining the quality, the purity, or the adulteration of the madders. In most cases calcination is sufficient; and rigorously, calcination and the test by dyeing made conjointly, allow the practitioner to form a positive opinion of the value of the madders submitted to examination. *Girardin. (Chem. Gaz. ii.)*

MAGISTERY. The alchemical term for precipitates, especially those produced by the dilution of metallic solutions with water. It is still retained as the vulgar title of several preparations, an example of which is the magistery of BISMUTH.

MAGNESIA ALUM. See ALUMS.

MAGNESIAN LIMESTONE. See BITTER SPAR.

MAGNESITE. See BITTER SPAR and MEER-SCHAUM.

MAGNESIUM. The metallic basis of magnesia. The earth was first employed about 150 years ago; it was distinguished from lime about the middle of the last century, and within the present century the metal was isolated by H. Davy. It is most abundantly found in limestones, in which it sometimes exists in equal proportion with lime. It is also present in mineral and sea-water, in nearly all clays and slates, besides talcose and other rocks. In plants and animals it plays an important part, chiefly in the harder portions as a phosphate.

1. *Magnesium* may be prepared by putting potassium in the lower end of a tube, and above pieces of fused chloride of magnesium, which

are first heated nearly to fusion, and then by inclining the tube the potassium is allowed to flow upon the chloride. Strong ignition ensues with the formation of magnesium and chloride of potassium, the latter of which is washed out. It is silver-white, lustrous, malleable, ductile, and readily fusible, and by galvanism is obtained in 8-hedra. It is permanent in dry, oxidizes slowly in moist air, burns when heated highly; oxidizes slowly in hot water, readily in acid water. Sym. Mg. Eq. = 12, (158.35. O = 100 or 12.67. H = 1. Berz.)

2. *Magnesia*. Magnia, calcined or caustic magnesia. Ger. Talkerde, Bittererde. MgO. Obtained by heating the carbonate or hydrate; from the former as a white, very loose powder, from the latter more dense. It slightly blues moistened red litmus paper, but is not caustic; fuses by galvanism or the hydroxygen blowpipe. It forms a *hydrate* which is precipitated from solutions by caustic fixed alkali, and dries to an almost translucent, brittle mass (found in nature as HYDROUS MAGNESIA). It is soluble in about 5000 pts. cold, and 36000 pts. boiling water. When moistened with nitrate of cobalt, and heated to redness before the blowpipe, it becomes rose-red.

Salts. This earth has not a very strong attraction for acids, except the sulphuric and phosphoric. Its soluble salts have a bitter taste; the insoluble salts are soluble in muriatic acid, except the ignited phosphate. Caustic potassa or soda precipitates magnesia perfectly, unless ammoniacal salts be present; ammonia and carbonated alkalies precipitate it imperfectly; borate or phosphated alkali throws it down imperfectly, even when heated; but if free ammonia be present, the double phosphate of ammonia and magnesia removes nearly all the earth from solution; oxalic acid and oxalates throw it down from neutral and alkaline solutions, which is prevented by sal-ammoniac.

3. *Sulphuret*. By passing sulphuretted hydrogen through magnesia in water, it is dissolved, forming sulphhydrate of sulphuret of magnesium. If a concentrated solution of sulphhydrate of potassium be added to this solution, hydrated sulphuret of magnesium precipitates.

SALTS.

1. *Haloids*.—*Chloride of Magnesia* occurs in sea-water and salines. The solution is made by dissolving magnesia in muriatic acid. By evaporating equal parts of the muriate and salammoniac to dryness, and putting it gradually into an ignited platinum crucible, or by igniting 1 pt. magnesia and 2 pts. salammoniac until all ammoniacal salt is volatilized, fused, dry chloride of magnesium is formed. It is very fusible and unaltered apart from water, but by water and heat is resolved into muriatic acid and magnesia. The hydrous salt crystallizes with the form. $\text{MgCl} + 6 \text{HO}$. It forms a crystallizable double salt with chloride of potassium = $\text{KCl} + 2 \text{MgCl} + 12 \text{HO}$. The *bromide*, also formed direct, forms a dry and aqueous salt, the latter with the form. $\text{MgBr} + 6 \text{HO}$. The *iodide* crystallizes with difficulty. Both these salts are easily decomposed by heat, and all are deliquescent. The *fluoride*, formed

direct, is a white powder, bearing ignition without decomposition, insoluble in water, scarcely in acids.

2. *Sulphate*. Syn. Epsom salt. Ger. Bittersalz. It occurs in quantity in many salines, and may be obtained from them by crystallization, especially from the mother waters after the separation of common salt. It is also prepared direct by the solution of native carbonate of magnesia in dilute sulphuric acid; or from magnesian carbonate of lime by ignition, slacking with water, treatment with half as much pyroligneous acid as would be necessary to dissolve the whole, whereby lime is chiefly extracted, and the residue treated with sulphuric acid or copperas. The presence of sulphate of soda is known by treating its solution with carbonate of baryta, which renders it strongly alkaline; of a salt of iron by sulphuret of ammonium or prussiate of potash; of copper by sulphuretted hydrogen, which browns it. Iron, the most common impurity, is removed by digesting or boiling the solution with carbonate of magnesia or carbonate of lime. Epsom salt is in the form of needles, of the trichinate cryst. system, with the form. $\text{MgO}, \text{SO}_3 + 7 \text{HO}$. 1 pt. is soluble in 0.799 pts. water at 66°, and the solution has a spec. grav. = 1.293.

Per cent. of the Cryst. Salt in Solutions at 59°.

Sp. Gr.	Pr. Ct.	Sp. Gr.	Pr. Ct.	Sp. Gr.	Pr. Ct.
1.270...47.36	1.128...24.24	1.055...10.71			
1.230...41.17	1.111...21.26	1.043... 8.25			
1.174...33.33	1.098...18.69	1.029... 5.66			
1.150...28.58	1.080...15.25	1.010... 1.96			
1.140...26.47	1.064...12.28				

It is much more soluble in muriatic acid water than in pure water. A saturated solution below 32° forms crystals with 12 HO. By evaporating until a pellicle forms on the surface, or by heating Epsom salt to 126°, a salt is formed with 6 HO. By heating Epsom salt to 212° over oil of vitriol in vacuo, it loses 5 eq. HO; by heating it in the air to 270° it loses 6 HO, while the last eq. HO requires over 400° for its expulsion. Epsom salt forms a double salt with potassa, which occurs in sea-water and salines, with the form. $\text{KO}, \text{SO}_3 + \text{MgO}, \text{SO}_3 + 6 \text{HO}$. A salt isomorphous with this one is formed with sulphate of ammonia. The soda double salt has a similar formula with 6 HO.

The hyposulphate (dithionate) formed from Epsom salt and the barytic dithionate, is crystallizable. The sulphite, formed direct, a white powder or in fine crystals, is soluble in 20 pts. water. By boiling the sulphite with flowers of sulphur, dithionite or hyposulphite is obtained, crystallizable, permanent in air.

3. *Carbonate*. Carbonate of magnesia, dissolved in carbonic acid, and exposed to great cold in winter, forms crystals with the form. $\text{MgO}, \text{CO}_2 + 5 \text{HO}$; by keeping the solution at 122° it crystallizes as $\text{MgO}, \text{CO}_2 + 3 \text{HO}$; by evaporating to dryness, it forms crystals, resembling arragonite = MgO, CO_2 .

Magnesia or subcarbonate of magnesia is prepared by precipitating Epsom salt with carbonate of soda. The more dilute the solution, the looser is the precipitate, and by freezing it while still moist, it becomes still looser. By

heating the solutions, the precipitate is more dense, but a portion of carbonic acid passes off, the more, the longer and higher it is heated. By precipitating in the cold, more neutral hydrate is formed, but a considerable quantity of magnesia remains in solution, from the formation of an acid salt; heat expels the excess of carbonic acid, and the magnesia almost wholly precipitates as a basic salt. The quantity of magnesia varies in the precipitate, according to the mode of preparation, from 33 to 43 pr. ct. A double carbonate is formed by mixing muriate or nitrate of magnesia with an excess of bicarbonate of potassa, and has the form. $\text{KO}, 2\text{CO}_2 + 2(\text{MgO}, \text{CO}_2) + 9\text{HO}$. A similar salt is similarly made with bicarbonate of soda; and both are decomposed by water. The ammonia double salt is $\text{NH}_3, \text{CO}_2 + \text{MgO}, \text{CO}_2 + 5\text{HO}$.

4. *Nitrate* is formed direct and crystallizes on cooling a concentrated solution with the form. $\text{MgO}, \text{NO}_5 + 6\text{HO}$. By fusion at 600° it loses 5 eq. water. *Chlorate* of magnesia resembles the salt of lime. The *hypochlorite* with MgCl , made like bleaching salt, has similar properties. The *perchlorite* is deliquescent, crystallizable, soluble in alcohol. The *bromate* crystallizes in regular 8-hedra, and is soluble in 1.4 cold water.

5. A basic *Phosphate* is formed by precipitating Epsom salt with common phosphate of soda; and a white powder, which dried at 212° is $3\text{MgO}, \text{PO}_5 + 5\text{HO}$; fuses to a clear glass at a white heat and is still soluble in acids. The ignited salt contains 54.34 pr. ct. phosphoric acid and 45.66 pr. ct. magnesia. It occurs in bones, calculi, plants, in the hull of grain, &c. The neutral salt is formed by adding phosphoric acid to acetate of magnesia and slowly evaporating; or by mixing 2 pts. Epsom salt in 32 water with 3 pts. phosphate of soda in 32 water, and setting aside to crystallize. Form. $2\text{MgO}, \text{PO}_5, \text{HO} + 14\text{HO}$, of which water 8 eq. pass off at 212° , 6 more at 350° , and the last at a still higher heat; when heated to redness it is insoluble in acids. 1 pt. of the cryst. salt is slowly soluble in 322 pts. cold water, which at 212° deposits a part, which will not all redissolve on cooling; it is readily soluble in acid water. An acid salt announced by Gregory is made by heating magnesia or a phosphate with an excess of glacial phosphoric acid. It is wholly insoluble in water, and has the formula $3\text{MgO}, 2\text{PO}_5$.

Pyrophosphate is precip. from Epsom salt by adding carbonate of ammonia, in an excess of which it redissolves. Metaphosphate is thrown down only from acetate of magnesia. Hypophosphite and phosphite are crystallizable; the former with the form. $\text{MgO}, \text{PO} + 8\text{HO}$; the latter forms a double salt with ammonia.

The double phosphate of magnesia and ammonia is found in some calculi, &c. and is always formed when phosphoric acid, magnesia, and ammonia come together, but it separates slowly from the liquid, and only then entirely when an excess of phosphate is present. It forms fine prisms or a white crystalline, gritty powder, insoluble in water containing phosphate, scarcely soluble in pure water and other saline solutions. Its form. is $\text{NH}_3, 2\text{MgO}, \text{PO}_5 + 13\text{HO}$; by heat it loses water

and ammonia, and the residue, $2\text{MgO}, \text{PO}_5$, contains 36.67 pr. ct. magnesia.

6. *Borate*. Boiling solutions of Epsom salt and borax mixed, precipitate a gelatinous borate, $3\text{MgO}, \text{BO}_3 + 9\text{HO}$, which after washing with cold water and drying is white and earthy; slightly soluble in water, with alkaline reaction, becomes cloudy by boiling. $\text{MgO}, 3\text{BO}_3 + 8\text{HO}$.

A triborate is obtained in granular crystals by boiling an excess of caustic or carbonate of magnesia with boracic acid, filtering, and evaporating. It acts alkaline; fuses with loss of water and some acid; loses all its acid by boiling water; soluble in 75 pts. cold water. A sexborate has also been formed, consisting of $\text{MgO}, 6\text{BO}_3 + 18\text{HO}$. Borate of magnesia tends to form double salts with potassa, soda, ammonia, and lime, that of lime being found as HYDROBORACITE; that of soda forms large crystals with the form. $\text{NaO}, 2\text{MgO}, 5\text{BO}_3 + 30\text{HO}$.

7. *Silicate*. $2\text{MgO}, \text{SiO}_3$ and MgO, SiO_3 fuse in a blast furnace to an enamel. Many simple and compound silicates occur in nature, TALC, SERPENTINE, AUGITE, HORNBLende, &c.

MAGNET. } *Min.* Native Magnet.

MAGNETIC IRON. } *Ger.* Magneteisentein.

Cryst. Regular, exhibiting the forms Pl. VIII., figs. 1–12, and Pl. IX. fig. 52, a twinned 8-hedron, cleavage parallel to 8-hedron. It occurs also granular, almost compact, and earthy. $H. = 5.5 - 6.5$. $G. = 5.09$. Black; metallic, submetallic; opaque; somewhat brittle, with subconchoidal, shining fracture, and a black powder. Attracted by the magnet, and often exhibiting polarity. Scarcely fusible in the reducing flame, and changing to brown peroxide in the oxidizing flame. Dissolves with green color in borax in the inner flame, to a yellow or brownish red glass in the outer flame. Soluble in muriatic, not in nitric acid. Distinguished from specular iron, partly by magnetism, but more certainly by its black streak. Form. $\text{FeO}, \text{Fe}_2\text{O}_3 = \text{Fe}_3\text{O}_4$, containing 69.03 $\text{Fe}_2\text{O}_3 + 30.97\text{FeO}$, or 71.68 pr. ct. metal. There is doubtless a hydrate among some of the magnetic ores, similar to that made by Wöhler, with 7 pr. ct. water; for Berthier gives the analysis of one containing 67 pr. ct. peroxide, 15 pr. ct. protoxide, and 6 pr. ct. water. He ascribes the magnetic property to a protosilicate, but the 2 pr. ct. of silica it contains is not sufficient for this purpose.

Local. Large beds and veins of this ore occur in igneous and altered rocks, more rarely in secondary formations. Celebrated are the mines of Sweden and Lapland. Large formations are found in the counties to the W. and S. W. of Lake Champlain, N. Y.; in the N. of New Jersey; in Berks, Chester, and Lebanon counties, Penna. 8 and 12-hedral crystals occur at Cornwall, Lebanon Co., Penna., with earthy ore, having strong polarity. These beds contain a considerable proportion of flux in them, and yield an excellent quality of iron with a tendency to a hot short character.

MAGNETIC PYRITES. See IRON PYRITES.

MAGNETISM. See ELECTRICITY.

MAGNUS SALT. See PLATINUM.

MAIZE. *Agric.* Syn. Indian Corn. Jones, Mason and Burnet's analyses (*Journal of Agri-*

MALACHITE.

culture, Vol. 3, p. 412) gives as the per centage composition of the grain:—

Starch	72
Gluten, Albumen.....	12.50
Fat	9.2
Woody fibre.....	6.3

The ash of the grain forming 1.6 pr. ct. contains—

Lime	1.5
Magnesia	17.6
Alkalies	23.3
Silica	2.4
Phosphoric acid	51
Sulphuric acid	1.3
Oxide of iron, alumina, &c.....	1.8
Carbonic acid	.9

The ashes of the entire corn-stalk (grain only excepted) amount to 5.2 pr. ct., and consist of—

Lime	5.6
Magnesia	6
Alkalies	3
Silica	78.5
Oxide of iron and alumina.....	1.8
Phosphoric acid.....	3.6
Sulphuric acid	1.5

Lagrange proposes to detect the presence of even 4 or 5 pr. ct. of corn meal in wheat flour, by mixing and stirring together in a test tube, 2 grms. of the sample with 4 grms. of nitric acid, then adding 60 grms. water, and afterwards 2 grms. of carbonate of potassa dissolved in 8 grms. water. If no corn meal is present, as soon as the carbonic acid has escaped, only yellowish flakes separate; in the contrary case, orange yellow particles subside and are easily detected. (*Journ. de Chem. Med.* iv. 339.) In Indiana, sugar has been made from the juice of the stalks.

MALACHITE. *Min.* Green Malachite, Mountain Green. Cryst. Oblique Rhombic, prismatic, with perfect basal cleavage. Usually in fibrous groups, compact and earthy, often stalactitic. $H. = 3.5 - 4$. $G. = 4$. Various shades of green, bluish, yellowish, and grass green; with a vitreous lustre in well-defined crystals, sometimes dull; translucent, opaque. Behaves chemically like BLUE MALACHITE. Form. $CuO, CO_2 + CuO, HO$, containing 57.66 pr. ct. metal.

Local. Mostly with other ores of copper, especially near the surface. Cheshire, Connecticut; copper mines, New Jersey; Perkio-men on the Schuylkill, and Morgantown, Bucks Co., Penna., &c. Perfect crystals have been found at Mine à la Motte, Madison Co., Missouri.

MALACOLITE. See AUGITE.

MALIC ACID. Exists either in a free state, or combined in a large number of fruits and vegetables.

Prep. Everett procures it from the culinary rhubarb by first removing the cuticle from the leaf-stalk, and submitting them to pressure in a canvas bag, so as to obtain the juice; to this slaked lime is added till the solution becomes alkaline; it is then to be boiled and filtered. To the clear liquor add nitrate of lead, when a copious bulky precipitate of malate of lead forms; the whole is then to be brought to the state of ebullition, and the clear decanted solu-

MALIC ACID.

tion will deposit good crystals of malate of lead on cooling. The precipitated mass must be carefully washed, acted upon by sulphuric acid, gently heated, and the sulphate of lead thus formed separated by a filter; the other part of the malate of lead is then added to this solution, and sulphuretted hydrogen gas passed through until all the malic acid is set free. The author recommends this method in preference to making the whole of the malate of lead at once by this process. The sulphuret of lead is to be separated by filter, and the malic acid concentrated to a syrup in a water-bath. *Chem. Gaz.* i. 248.

It is also a product of the action of nitrous acid upon ASPARAGIN and *aspartic acid*, which, says Pereira, are two amides of malic acid, to which they bear the same relation as oxamide and oxamic acid do to oxalic acid.

Prop. Formula $C_3H_4O_5 = \bar{M}, 2 HO$. Is difficultly crystallizable, and, as generally obtained, is in a confused crystalline granular crust. Distinguished from tartaric, racemic, citric, and oxalic acids by its solution continuing clear when neutralized with lime-water, without regard to temperature. It is hygroscopic, very soluble in water and alcohol, fuses at 266° to 284° , but continued at this heat for a length of time becomes FUMARIC ACID. By brisk distillation it is transformed into a volatile product, *maleic acid* and *fumaric acid*, which remains in the retort. This latter acid, ultimately passing into oxalic by the continued influence of the reagent, is also generated by the action of concentrated nitric acid.

According to Rieckher, when malic acid, or one of its salts is heated with hydrate of potassa in excess, decomposition ensues, aqueous vapors escape, and a slightly colored mass is left, which contains acetic and oxalic acids, but no formic acid. Dessaignes found that, upon being fermented as malate of lime, it was, after three months, partially metamorphosed into succinic acid. *Comptes Rendus*, Jan. 1849.

Malic acid is bibasic, and its salts, excepting that of lead, are soluble in water; this latter is characterized by the fine silky needle which it assumes in the liquid from which precipitated. The formula of the neutral salts is $\bar{M}, 2 MO$ —that of the acid salts is $\bar{M}, MO, HO$.

The bi-malate of ammonia is remarkable for the facility with which it crystallizes. The malate of copper forms fine blue crystals;—the crystals of the *basic* copper salts are green. The malate of silver is a white powder.

Maleic Acid. $C_3H_2O_5, 2 HO$. Forms lamellæ or oblique rhombic prisms soluble in water, alcohol, and ether. It is isomeric with equiseti and aconitic acids, from which latter it chiefly differs in its behavior to heat, which at first transforms it into water and anhydrous maleic acid, but ultimately into paramaleic or fumaric acid. (*Liebig's Ann.* xlix. 57.) Like the malic acid, it is bibasic, the formula of its neutral salts being $\bar{M} + 2 MO$, and that of its acid salts $R + MO, HO$. The neutral salts are very soluble in water and alcohol, but do not crystallize. The maleates of the alkaline earths are crystalline, but the neutral earthy maleates neither form double salts with each other, nor with the neutral alkaline salts.

Buchner, Jr., gives the following formula for its salts:—

Neutral maleate of potash.....	$C_8H_2O_6$, 2 KO.
Acid maleate of potash.....	$C_8H_2O_6$, KO, HO + HO.
Neutral maleate of soda.....	$C_8H_2O_6$, 2 NaO + HO.
Acid maleate of soda.....	$C_8H_2O_6$, NaO, HO + 6 HO.
Maleate of potash and soda.....	$C_8H_2O_6$, NaO, KO.
Neutral maleate of barytes.....	$C_8H_2O_6$, 2 BaO + 2 HO.
Acid maleate of barytes.....	$C_8H_2O_6$, BaO, HO
Neutral maleate of silver.....	$C_8H_2O_6$, 2 AgO.
Acid maleate of silver.....	$C_8H_2O_6$, AgO, HO

Although the essential characters of a bibasic acid consist in the two atoms of hydrate water of the hydrated acid being susceptible of replacement by bases in the neutral salts, the bibasic maleates exhibit an anomaly in this respect, which is that the two atoms of hydrate water, which are not expelled at 212° , still occur in them almost without exception. It differs in this respect from tartaric acid, for in the neutral salts of this latter there is complete absence of hydrate water. M. Buchner inclines to the opinion that the hydrate water in the neutral maleates indicates that it is susceptible of being replaced by other neutral metallic maleates, and that in this manner several kinds of double salts may be formed; for instance, maleates of copper and potash, of nickel and potash, of zinc and potash, &c. *Chem. Gaz.* ii. 366, 367.

The maleates and paramaleates are isomeric, but the latter differ from the former in being monobasic. *Rieckher and Buchner.*

MALLEABILITY. The capability of extension under the hammer, almost exclusively applied to the metals. Gold is the most malleable, *i. e.* is capable of the greatest extension. It is not identical with laminability (extension between rollers) or ductility (drawing into wire), for iron is not very malleable, but is highly ductile; and zinc has little malleability, but considerable laminability.

MALLOW, MARSH. *Med.* The root of the *Althæa officinalis* contains, according to Buchner,—

Fatty oil.....	1-26
Glutinous matter.....	1-81
Uncrystallizable sugar and althein... 8-29	
Mucilage.....	35-64
Starch.....	37-51
Phosphate of lime.....	8-29
Vegetable medulla.....	11-05
Woody fibre.....	7-50

MALT. Barley softened in water, then exposed to air and moderate heat until incipient germination ensues, and afterwards kiln-dried, to destroy the vitality of the seeds, is termed malt—an important material in the brewing of BEER. During the process of malting, carbonic acid is evolved and oxygen probably absorbed, and the azotized matter of the grain transformed into DIASTASE, through the influence of which the starchy matter becomes saccharized, or, technically speaking, converted into “sweet worts.” See FERMENTATION.

MALTHACITE. *Min.* A white or yellowish, translucent substance, with feeble waxy lustre, allied to BOLE.

MANCINITE. *Min.* Brown, plumose, shining; it is a simple silicate of zinc from Mancino, near Leghorn.

MANGANESE. *Chem. Syn.* Magnesium. *Ger.* Braunsteinmetall. Known for a long time in one of its oxides, for decoloring glass. It occurs chiefly as oxide, either alone or in iron-ores; also as carbonate, and as silicate in Hornblende, augite, garnet, and many other silicates. *Sym. Mn.* Eq. 28 (344-684, O. = 100, or 27-57, H. = 1, *Berz.*)

1. *Manganese* is obtained with difficulty and probably as carburet, by mixing an oxide with lamp-black and oil, enclosing it in a crucible and giving a blast-fire for an hour. Grayish white, soft, brittle of sp. gr. 7—8. It is one of the most oxidable of the proper basic metals, oxidizing even in cold water slowly, very rapidly in acid water.

2. *Oxide of Manganese.* Protoxide, MnO, is obtained by igniting carbonate or oxide with carbon or hydrogen; or by fusing a mixture of equal parts of fused chloride of manganese and carbonate of soda with a little sal ammoniac and washing with water. It is a grayish green powder, caking by a high heat, forming sulphuret by ignition in sulphuretted hydrogen. The hydrate is thrown down white from its salts by an alkali, but rapidly browns by oxidation.

Salts. It is one of the strongest bases of the proper metals. Its salts are mostly soluble in water, and all in muriatic acid; they are colorless, or, if slightly rose-red, it is due to the presence of a small quantity of cobalt; bear a red heat if the acid be fixed. The fixed alkalies precipitate all the oxide from solution as a white hydrate, brown in the air; ammonia throws down only half of the oxide, the other half forming a double salt, but by long exposure all the oxide falls as a brown oxide. Carbonates of potassa and soda throws down a white carbonate, which does not brown by oxidation; bicarbonate of potassa does not throw it down if the solution be dilute and acidulated. Phosphate or arseniate of soda or prussiate of potash give white precipitates; oxalic acid and its salts give a white precipitate in strong solutions; red prussiate of potash gives a brownish yellow precipitate, insoluble in muriatic acid; sulphuretted hydrogen does not precipitate the salts of manganese if slightly acid; but sulphuretted alkali throws down a flesh-red precipitate, soluble in acid.

3. *Red Oxide.* $Mn_3O_4 = MnO, Mn_2O_3$. All the higher oxides by heat are reduced to red oxide, which occurs crystallized in nature as Hausmannite. It is either MnO, Mn_2O_3 , or 2 MnO, MnO_2 , and contains 72-41 pr. ct. metal, or as much surplus of oxygen as would make 37-93 pr. ct. binioxide. It is soluble in the strong acids in the cold, but by heat, as salt of oxide is formed.

4. *Sesquioxide.* Black oxide, Mn_2O_3 , found native as braunite, and formed by a low igni-

tion of binoxide. It contains 70 pr. ct. metal, or what is equivalent to 55 pr. ct. binoxide. It decomposes by boiling with nitric or dilute sulphuric acid into an oxide salt and the binoxide; by muriatic acid, chlorine, and by oil of vitriol, oxygen are evolved, soluble in cold sulphuric acid with a red color. Its hydrate, $Mn_2O_3 \cdot HO$ (MANGANITE), is formed by exposing the hydrated oxide to the air. See also PSILOMELAN and WARWICKITE.

5. *Binoxide*. Hyperoxide, peroxide, glass-makers' soap. *Ger.* Braunstein. MnO_2 . The most abundant and most valuable ore of manganese; see PYROLUSITE. Formed by gently heating other hydrated oxides, nitrate or carbonate, and extracting oxide by acid. It is black, shining, and contains 63.64 pr. ct. metal, or 81.82 pr. ct. oxide, or 87.88 pr. ct. red oxide. It loses by low ignition 9 pr. ct. oxygen; by a higher heat 12 pr. ct., and by a strong heat with oil of vitriol 18 pr. ct. There are several hydrates formed containing 1 pt. HO for 1, 2, 3, and 4 pts. MnO_2 , and the mineral WAD is a hydrate of this oxide.

Analysis. The native oxide, containing one or more of the above oxides, is only valuable for the amount of chlorine it will produce with muriatic acid, every equiv. of pure binoxide yielding one equiv. chlorine. Hence all the oxygen above MnO is estimated as binoxide, and the percentage of binoxide determines the value of the ore. The best method of analysis is that by sulphuric with oxalic acid, or an oxalate, this acid being converted into carbonic by taking up all the surplus oxygen. One equiv. of the oxide will convert 1 equiv. of oxalic acid into 2 equivs. of carbonic acid; thus $MnO_2 + C_2O_3 = MnO + C_2O_4$. 143 grs. of cryst. oxalic acid, or 152½ grs. dry oxalate of soda are just sufficient for 100 grs. pure binoxide, and would give off just 100 grs. carbonic acid. The operation is conveniently performed in the apparatus fig. 26, p. 188, under ANALYSIS. 50 grs. of the finely powdered oxide to be examined are introduced into the flask *a*, with 75 grs. or more of oxalic acid, or 80 grs. of oxalate of soda, and water to fill $\frac{1}{2}$ of the flask. Oil of vitriol is then drawn into the bulb *c*, which is corked, put into the flask, as in the figure, and the whole apparatus weighed. The sulphuric acid is gradually let down into the flask, and when the evolution of carbonic acid ceases, the apparatus is again weighed. The loss of weight doubled, expresses the per cent. of binoxide in the ore. A fine quality of ore should contain 80—95 pr. ct. binoxide.

6. *Manganic acid*. MnO_3 . An alkaline salt is formed by igniting an oxide of manganese with fixed alkali with access of air, or by alkali and chlorate or nitrate of potassa. Only the alkaline salts are known; those of potassa and soda are soluble in water, with a dark green color, but change readily by acid to red permanganate, while binoxide is precipitated.

7. *Permanganic acid*. Mn_2O_7 . A salt is formed by acting on a manganate by nitric acid. The acid is obtained by decomposing manganate of baryta suspended in water by sulphuric or carbonic acid, and decanting from the sediment. It forms a deep blood-red solution, which, if concentrated, may be heated, but, when dilute, decomposes before 212°. It yields oxygen

readily, and is a powerful oxidizer of inorganic and organic substances, except tin, chlorine, and bodies already highly oxidized. The salts of this acid have a brilliant red color, are all soluble, that of silver least so, and deflagrate with combustibles.

8. *Sulphuret*. MnS. Is found native as MANGANBLENDE. The dry sulphuret is formed by passing sulphuretted hydrogen over heated oxide, carbonate, sulphate, or hydrous sulphuret; by the decomposition of sulphate with carbon in a crucible. By the former it is dark olive-green, by the latter a porous, fused, semi-metallic mass. A flesh-colored compound is precipitated from manganese solutions by sulphuretted alkali, or by sulphuretted hydrogen from a weak acid: it oxidizes by washing and drying in the air. Völker prepared the sulphuret of a deep red color by passing sulphuretted hydrogen for some time through the acetate of manganese; and his analysis shows that it is an anhydrous sulphuret, when pure. (*Ann. der Chem.* 1847.) Völker has also shown that it forms double sulphurets with potassium and sodium, with the form. $3 MnS + KS$ and $3 MnS + NaS$.

Phosphuret, formed by fusion of the metal and phosphorus together, is white, brittle, metallic.

Carburet is formed when the oxides are reduced by carbon.

Siliciuret is formed of a steel gray color, insoluble in acids, when an oxide is reduced by carbon in contact with silica, at a very high temperature.

Alloys. Manganese alloys with several metals, as gold, silver, copper, tin, mercury, and iron, of which that with iron is the most important. It imparts to iron a whiter color, hardness, and brittleness; a little iron in manganese renders it magnetic, and diminishes its oxidability.

Uses. The oxides are used to remove color from glass, and hence the name glassmaker's soap. In larger quantity, they give a violet or amethyst tint to glass. The binoxide is extensively and exclusively used in the manufacture of chloride of lime; its excess of oxygen oxidizes the hydrogen of muriatic acid, and sets chlorine free.

SALTS.

1. *Haloids*. *Chloride*. Formed by solution of carbonate, or any oxide of manganese, in muriatic acid and evaporating. To obtain it pure, the oxide is first treated with dilute nitric acid to remove lime, and then converted into chloride. This is heated to dryness, and transferred to a crucible and heated to low redness, as long as fumes of acid escape, by which the iron becomes insoluble. Solution in water and slow evaporation gives rose-red, or sometimes colorless crystals, with the form. $Mn Cl + 4 HO$, they readily lose 2 eq. HO in dry air, but usually deliquesce; soluble in 0.66 water at 50°, and in still less hot water; readily dissolve in alcohol, not in ether or turpentine. The dry chloride fuses apart from air, and congeals again to a crystalline mass.

A volatile perchloride is formed by evaporating permanganate of potassa to dryness, dissolving the residue in oil of vitriol in a

retort, and adding pieces of fused chloride of sodium as long as colored vapors rise. The vapors condense, cooled from $+4^{\circ}$ to -5° , to a brown liquid. It is probably manganate of terchloride of manganese, like the chrome compound.

Bromide; formed direct, yields a reddish solution which may be dried to a red powder, which is deliquescent, and by heating in the air becomes red oxide with loss of bromine. *Iodide*, similarly made, yields a white crystalline mass, with similar properties. *Fluoride*, made direct, gives pale amethyst crystals or powder, not decomposable by ignition. A sesquifluoride, formed direct and allowed to evaporate, yields ruby-red crystals; soluble in a little water without change, but by dilution or boiling precipitating a basic salt, while an acid salt remains in solution. A perfluoride is obtained by mixing 2 pts. manganate or permanganate of potassa, and 1 pt. fluorspar in a platinum retort and pouring oil of vitriol over the mixture. The yellow vapor rising decomposes with glass into fluoride of silicon and permanganic acid, with water into fluohydric and permanganic acids. The double fluorides of manganese with potassium and sodium are obtained by precipitating sulphate of manganese by the alkaline fluorides.

2. *Sulphates*. *a. Protosulphate*. Bin oxide of manganese heated with oil of vitriol yields oxygen and protosulphate. To make it pure, free the ore from lime by nitric acid, mix it with an equal weight of oil of vitriol, and ignite it for an hour, (which decomposes sulphate of iron and copper,) and dissolve in water. The ore may also be heated with 4 times as much cryst. copperas, or $\frac{2}{3}$ as much anhydrous copperas, and dissolved. In both cases the sulphate contains a little sulphate of cobalt. The cold saturated solution, at 25° to 40° , yields pale rose-red crystals, of the form of copperas, with the formula $\text{MnO}, \text{SO}_3 + 7 \text{HO}$. If this salt be treated with cold absolute alcohol, or if the solution be evaporated at 50° to 60° , crystals are obtained of the same form as blue vitriol with 5 HO. By evaporation at 70° to 80° , large right rhombic, usually rose-red crystals are obtained, with 4 HO; and a crystalline crust is often deposited at the same time with 3 HO. By fusing the crystals with 7 HO, or boiling them with alcohol, the salt retains still 2 HO. By rapidly evaporating an acid solution, the reddish powder has 1 HO; and by heating any of the crystals, the white anhydrous salt is obtained. The dry salt bears a red heat without decomposition; it contains 47.37 pr. ct. oxide. The dry salt is soluble in 1.78 pts. water at 43° .

This salt forms double salts with the sulphates of potassa, soda, and ammonia with 6 eq. HO, of the same form as the double sulphate of magnesia and ammonia. A double salt with soda has also been observed, containing 2 HO.

b. Sulphate of Sesquioxide. By the action of cold dilute sulphuric acid on the red oxide, a dark red solution is obtained, containing this salt. It forms double salts with sulphates of potassa and ammonia, having the octahedral form of the ALUMS, but with a deep amethystine color.

c. Hyposulphate. (Dithionate.) Boil black oxide with nitric acid to remove lime and hydrated oxide, and pass sulphurous acid through it, suspended in water.

d. The sulphite is formed by passing sulphurous acid through the carbonate of manganese suspended in water until it smells strongly of it, and boiling the solution, which precipitates the salt as a white crystalline powder, permanent in air, nearly insoluble in water and alcohol, and soluble in sulphurous acid; form. $\text{MnO}, \text{SO}_2 + 2 \text{HO}$.

e. The hyposulphite is formed by passing sulphurous acid through the freshly precipitated sulphuret.

3. *Nitrate*. Is formed by dissolving carbonate in nitric acid, crystallizes with difficulty with 6 HO. The nitrite and nitrate are deliquescent.

4. *Phosphate*. Occurs in HURAULITE and HETEROZITE. Formed by precip. with phosphate of soda as a white powder, slightly soluble in water and ammoniacal salts; boiling potassa solution extracts from it all its phosphoric acid. Bödecker (*Lieb. Ann.* 1849) precipitates sulphate of manganese by an excess of phosphate of soda, divides the solution with its precip. into two parts, dissolves the precipitate in one in muriatic acid, adds the two parts together, and suffers it to stand, during which, the amorphous deposit changes into colorless prisms of the form. $2 \text{MnO}, \text{PO}_5 + 7 \text{HO}$. The same salt is prepared by Heintz, (*Chem. Gaz.* vi. 488,) by acidulating the sulphate with acetic acid and adding phosphate of soda until the precipitate becomes permanent. When the ordinary precip. of phosphate of manganese is dissolved in phosphoric acid and evaporated, a salt crystallizes out, with the form. $\text{MnO}, \text{PO}_5 + 4 \text{HO}$. The salt formed by precipitating sulphate by an excess of phosphate of soda is $3 \text{MnO}, \text{PO}_5 + 7 \text{HO}$. (*Heintz.*) A double salt is formed by heating in a flask a solution of chloride of manganese, muriatic and phosphoric acids, supersaturating with ammonia and closing the flask; white pearly scales, of the form. $\text{NH}_4\text{O}, 2 \text{MnO}, \text{PO}_5 + 2 \text{HO}$. Heintz prepares the same salt by dropping phosphate of soda into a faintly ammoniacal solution of sulphate of manganese. A triple pyrophosphate is formed by dissolving ignited phosphate of soda in hot water, adding ammonia and phosphate of manganese; its form. is $(\text{NH}_4\text{O}, \text{MnO}, \text{PO}_5) + (\text{NaO}, \text{MnO}, \text{PO}_5) + 6 \text{HO}$. A phosphate of sesquioxide is formed by heating concentrated phosphoric acid with bin oxide or red oxide; a violet mass, giving a red solution.

5. *Borate*. Borax gives a white precip. with protosalts of manganese.

6. *Carbonate* is found in nature, as manganese spar. A hydrated carbonate is thrown down from manganese salts by alkaline carbonates. According to Turner and Ure, its composition is $3 (\text{MnO}, \text{CO}_2) + 2 \text{HO}$; according to Forchhammer, $\text{MnO}, \text{CO}_2 + \text{HO}$. See MANGANESE, SILICATES.

Salts of Manganic and Permanganic acids. The *manganates* are formed by igniting alkaline nitrates, or the caustic alkalies with access of air, with bin oxide of manganese and dissolving in water. The salt of potassa is obtained in crystals by evaporation in vacuo over oil of

vitriol, and have the form of sulphate of potassa; form. KO, MnO_3 . The salt of soda is too soluble to obtain in distinct crystals. The salts of baryta and strontia are green powders, permanent when dry.

The *permanganates* are made by boiling solutions of the manganates, or by the action of nitric acid on them. Wöhler's method for the salt of potassa is convenient; it consists in fusing chlorate of potassa over a lamp, adding caustic potassa, then an excess of binoxide, and heating until the chlorate is decomposed; the mass is boiled with a little water, which converts the green manganate into the red permanganate, decanted while still hot, and allowed to crystallize on cooling. Dark purple-red crystals, $\text{KO}, \text{Mn}_2\text{O}_7$, permanent in air, of the same form as the perchlorate, dissolving in 16 pts. water at 59° , with same purple color; the solution passes through violet and blue to green, upon adding potassa and heating, and is easily decomposed by acids or heat, precipitating peroxide or its hydrate; by all substances having an affinity for oxygen, and by all organic bodies. The salts of soda, strontia, lime, and magnesia, are deliquescent; that of ammonia is permanent, and crystallizes in the same form as the salt of potassa; those of lithia and baryta are crystallizable, the latter being almost black and of the same form as dry sulphate of soda. There are also permanganates of zinc, copper, and silver.

MANGANESE ALUM. See ALUM.

MANGANESE BLENDE. *Min.* Mangan-glanz. Cryst. Regular, cleaving to a cube; also granularly massive. $H. = 3.5-4$. $G. = 3.95-4.014$. Iron-black and rich bronze-brown; submetallic; green streak. When roasted on coal, it fuses in the reducing flame on the edges to a brown slag, and gives with the fluxes the usual reactions of manganese; soluble in muriatic acid, giving off sulphuretted hydrogen. Form. MnS . *Local.* Nagyag, Transylvania, and Mine à la Motte, Missouri.

MANGANESE SPAR. *Min.* Syn. Allagite, Diallogite, Photizite, Rhodochrosite, Rhodinite. Cryst. Rhombic, Rhombic, parallel to which it cleaves; globular and botryoidal forms, with columnar structure; also granular and compact. $H. = 3.5$. $G. = 3.592$. White to rose-red; lustre vitreous; translucent, subtranslucent; brittle with uneven fracture. It usually decrepitates, and assumes a brownish or black color; gives the usual reactions of manganese; soluble with effervescence in heated muriatic acid. It is essentially MnO , CO_2 , with variable quantities of $(\text{CaO}, \text{MgO}, \text{FeO})\text{CO}_2$. *Local.* Silesia, Nagyag, Kapnik, &c.

MANGANITE. *Min.* Gray Manganese. Cryst. Right rhombic, prisms usually striated longitudinally; also columnar, granular. $H. = 4-4.5$. $G. = 4.3-4.4$. Color steel or iron-black, submetallic, with a dark reddish brown streak; opaque; rather brittle. It yields water in a tube, and gives the usual reactions of manganese; soluble by heat in muriatic acid, giving off less chlorine than pyrolusite. Form. $\text{M}_2\text{O}_3 + \text{HO}$. *Local.* Bohemia, Saxony, Harz, Scotland, &c. It is an inferior ore for generating chlorine.

MANGANOCALCITE. From Schemnitz; has

the same relation to manganese spar that arragonite has to calcareous spar. *Rammelsberg.*

MANGANOSILICATE. *Min.* Manganese spar, including also allagite, &c. The silicates of manganese have not been accurately defined, except those allied to AUGITE. The reddish silicate from Franklin, N. Jersey, called fowlerite, has, according to Thompson's analysis, the form. $3 \text{MnO}, \text{SiO}_3$; and to a black silicate from Klapperud, Dalecarlia, Sweden, Berzelius gives the form. $3 \text{MnO}, \text{SiO}_3 + 3 \text{HO}$. Troostite (*Thomson*) has the same form. as fowlerite, but $\frac{1}{3}$ of the MnO is replaced by FeO . Berzelius regards Boudant's marceline as $3 \text{Mn}_2\text{O}_3, \text{SiO}_3$. Most of the carbonates of manganese contain silicate at the same time, and resemble in this respect chrysocola and calamine.

MANIPULATION. Under this head are embraced all the mechanical operations of the LABORATORY. The manipulations in analysis are the most delicate, and require more care and accuracy than are bestowed in larger operations. The most convenient and expeditious methods, together with the appropriate apparatus, are given under the several articles of ANALYSIS, DISPLACEMENT, DRYING, &c. For details, see "Faraday's Chemical Manipulations," "Morfit's Chemical and Pharmaceutical Manipulations," and "Redwood & Proctor's Practical Pharmacy."

MANNA. The concrete exudation of the *Ornus Europæa*. It exists also in several fungi, the *Cantharellus esculens*, *Clavellaria coralloides*, *Agaricus piperatus*, and, according to Stenhouse, in the *Laminaria saccharina* and several species of sea-weeds.

Flake manna, or *manna cannulata*, is the selected variety; the *manna in sorts* being of inferior quality. Leuchtweiss's analysis of the two kinds gave—

	Flake Manna.	Manna in sorts.
Water.....	11.6	13.0
Insoluble foreign matters	0.4	0.9
Sugar.....	9.1	10.3
Mucilaginous body with man- nite, resinous and acid mat- ters, and also traces of nitro- genous matter	40.0	40.8
Ash.....	1.3	1.9
Mannite	42.6	37.6

The manna loses its water at 212° , and becomes brown and deliquescent. Its ashes consist principally of potassa, lime, magnesia and iron, phosphoric, muriatic, and sulphuric acids.

Mucilage. In combination with lead gives $\text{C}_6\text{H}_4\text{O}_5$ as its formula.

Acid. Extracted by ether in connection with the resin. Its aqueous solution is unaltered by sulphuric and muriatic acids, and the yellow color imparted by carbonated and caustic alkalis disappears on the addition of either of these acids. It is distinguished from lactic acid by giving no precipitate with salts of zinc. The precipitate formed by the acetate of lead is yellow, and insoluble in ammonia. By distillation a slightly acid, fetid liquor, incapable of reducing salts of silver, is generated.

Mannite. To obtain it pure the sugar must first be destroyed by fermentation. On evaporating the filtered solutions to crystallization,

and then adding as much boiling alcohol of 0.833 as is requisite for perfect solution, the greater portion of the mannite crystallizes out on cooling, and may be purified and whitened by washing with cold spirit.

Prop. Has recently been found by Reinsch in the root of the *Meum Athamanticum*, and is also a product of the viscous fermentation of cane and grape sugar. Formula $C_{12}H_{14}O_{12}$. Melts at 331° , and solidifies again at 324° . Crystallizes in colorless, silky prisms, has a sweet taste, and is very soluble in water and boiling alcohol, but scarcely so in cold alcohol. Fused with hydrate of potassa, it swells into a frothy mass, which, when supersaturated with sulphuric acid and subjected to distillation, yields acetic and traces of formic acids, along with the *metacetic* acid. (*Gottlieb.*) Its aqueous solution dissolves the oxide of lead, and is not fermentable. Nitric acid converts mannite into oxalic and saccharic acids.

Favre's examinations of mannite show that it is soluble without change in dilute potassa, baryta, and lime solutions, and also that it combines with lead in several proportions.

Mannitate of lead. Drops in asbestos-like laminæ, from a cooling concentrated solution of mannite, to which an excess of hot ammoniacal solution of acetate of lead has been added. When separated by filtration and dried in vacuo over sulphuric acid and lime, they are white, and have the formula $2 PbO + C_6H_5O_4$. In this combination, therefore, the mannite parts with 2 equivs. of water.

Mannite and Sulphuric acid. On pouring concentrated sulphuric acid over mannite, it dissolves to a colorless solution, but with evolution of heat; it is diluted with water, neutralized with chalk, the liquid decomposed with acetate of barytes, and the sulphate of barytes removed by filtration. The solution obtained is rendered turbid on boiling by the separation of some sulphate of lime; alcohol precipitates mannito-sulphate of lime; neutral acetate of lead affords a slight, basic acetate, an abundant precipitate. On collecting the latter on the filter, washing it with boiled distilled water, pressing it between blotting-paper, and drying it in vacuo, it formed a white powder insoluble in water, soluble in acidulated water without effervescence and without liberation of acetic acid, and which, dried at 266° , gives $C_6H_5O_4$, $2 SO_3$, $4 PbO$. The compound is decomposed with difficulty by boiling water, and even when it is dissolved in nitric acid it is a considerable length of time before it deposits sulphate of lead.

If the lead compound is decomposed by sulphuretted hydrogen, and the filtered liquid concentrated in vacuo, the mannito-sulphuric acid is obtained in solution; it does not precipitate salts of barytes and lime in the cold, but only when boiled. (*Chem. Gaz.* ii. 386, 387.)

Mannite may be distinguished from cane sugar in remaining uncolored by the action of sulphuric acid and a gentle heat. Unlike grape sugar also, it dissolves in hot soda or potassa solutions without color, and when heated with solution of potassa or sulphate of copper, does not precipitate the red oxide of the latter metal. *Stenhouse.*

The mannite found by Völeker in the *Triticum repens*, consists of $C_8H_8O_8$.

MANURES. *Agric. Chem.* Any substance, whether gaseous or solid, capable of promoting the growth of vegetation, or in other words of furnishing any or all of the constituents necessary to the germination and increase of plants, may, in a general sense, be considered a manure. By way of distinction, the term is sometimes limited to matters of organic origin, as dung, containing at the same time the requisite alkaline and earthy salts; that of *stimulants* is given to those saline and other matters which are supposed to *promote* the assimilation of the principles constituting manures, as lime, gypsum, and salt; and the title of *ameliorators* or *amendments* to such substances as improve the physical condition of the soil, that is, render it more compact, if too permeable, and vice versa. Some few manures combine in themselves all these properties.

In the application of manures, the selection should be with a view to the composition of the soil, and also of that of the crop intended to be grown upon it, and to this end the analytic tables in the "Farmer's Guide" will afford great facility.

Manures may be divided into two groups, viz. organic and inorganic. Among the first are those yielding nitrogen, oxygen, hydrogen, and carbon. Carbon and oxygen are furnished by the atmosphere, oxygen and hydrogen by the water, and nitrogen from both the air and organic matter. The efficacy of the latter depends upon the rapidity and manner of its decomposition. Such as ferment gradually are more potential and durable than those of quick decomposition, which lose their fertilizing influence in one season. Inorganic manures, on the other hand, are those which furnish the fixed constituents of the plant, which are found in its ashes. Of the first, the best are the excreta of animals, (barn-yard dung and GUANO, Poudrette and Flemish manure holding the foremost rank,) dried blood and flesh, fish offal, bone dust, and animal black. Following these may be named certain nitrogenous mineral substances, as tangle, soot, and vitriolic ashes. All of these, by reason of their contents of fixed and earthy salts, play their own part, and that of those in the second category, the inorganic manures, which may be enumerated as LIME, MARL, ashes, nitrates of potassa and of soda, common salt, plaster, gas lime, and GREEN SAND. Artificial manures, compounded according to the nature of the soil and crop which they are intended to nourish, are now made in Europe on a large scale.

For details as to the action and preparation and application of manures, see the article AGRICULTURE, *Liebig's Agricultural Chemistry*, *Farmers' Encyclopedia*, *Boussingault's Rural Economy*, *Dumas's Chimie*, vol. 8, and *Farmers' Library*, vol. 3, *Thaer's Principles of Agriculture*.

MARBLE. *Tech.* Compact and crystalline carbonates of lime, capable of being cut and polished, are termed Marbles.

MARCASITE. See MISPICKEL and IRON PYRITES.

MARCELINE. See MANGANOSILICATE.

MARCKANITE. See OBSIDIAN.

MARGARIC ACID. See MARGARIN.

MARGARIN. Formula $C_{74}H_{74}O_{12}$. A solid crystalline constituent of fats, especially those of vegetable origin, though it is also largely predominant in human and goose fat.

Prep. 1. By evaporation of the ethereal liquid containing the soluble portions of suet or tallow, dissolving the residuum in alcohol, and crystallizing out. 2. By freezing olive oil, separating the solid deposit by pressure, and purifying it by solution in and recrystallizations from alcohol.

Prop. Fuses at 118 to 120. More soluble in boiling than cold alcohol; dissolves readily in ether and spirits of turpentine. The principal products of its distillation are margaric acid and acrolin; of its saponification, margaric acid and glycerin, though it has been doubted whether the margaric acid obtained from vegetable oils is identical with that from animal fats. Sulphuric acid in small quantities abstracts the glycerin from margarin, but in larger portions generates new compounds, among which are the metamargaric and hydromargaritic acids.

Margaric acid. Form. $C_{34}H_{33}O_3$, HO. Crystallizes in white pearly scales, and hence its name from *μαργαρίτη*, a pearl. It exists in the residue of the distillation of brandy, but is procured by saponifying olive oil with potassa, and can also be obtained by boiling stearic acid with an equal weight of nitric of 1.273. The concrete portion found on cooling, by pressure and repeated crystallizations from alcohol, becomes pure margaric acid. It is likewise a product of the action of nitric acid upon oleic acid in the early stage of the process.

Prop. Fuses at 140° , and therein differs from stearic acid, to which it is very analogous. Insoluble in water, but soluble in ether and alcohol, the latter solution having an acid reaction. Nitric acid transforms it into suberic, pimelic, adipic, and succinic acids. Distilled in vacuo it passes over unaltered, but by access of air, is partially decomposed into carbonic acid and *margarone*, a volatile matter more abundantly generated when lime is also present.

Margarone. $C_{33}H_{33}O$. A pearly white, friable solid, electric by friction, fusible at 170.6 , more soluble in absolute than common alcohol, equally soluble in ether and acetic acid, but most readily in spirits of turpentine. (*Bussy.*) Forms no union with bases; is scarcely affected by nitric acid, but is carbonized by sulphuric acid.

Pyromargarol. Produced by the distillation of margaric acid upon liquid phosphoric acid. It is a brown solid substance, fusible between 140° and 150° , and soluble in ether. Its composition is one equivalent of water less than that of margaric acid, or $C_{34}H_{33}O_3$, and is distinguished and separable therefrom by its insolubility in a hydro-potassic solution.

Metamargaric acid. Crystallizes in brilliant solid lamellæ from alcohol, and in a needly mass by fusion. Fuses at 122° , soluble in alcohol and ether, insoluble in water, and partially decomposable by heat. (*Fremy and Miller.*)

Hydromargaritic acid. Crystallizes in friable rhomboidal prisms, which fuse at 154.5 , and are soluble in alcohol and ether, but insoluble in water. By distillation it is decomposed into water and metamargaric acid.

Hydromargaric acid. This, as well as the

two preceding acids, of which it is a compound, behaving like a single acid, are said to be bibasic. It crystallizes from an alcoholic solution of a mixture of equal portions thereof. It fuses at or near 140° .

Margaric acid. Formed by the action of gaseous ammonia upon melted margarin or margaric acid. Is soluble in alcohol, and crystallizes in small plates or prisms, and fuses at 140° . Its formula, according to Boullay, is $C_{34}H_{33}O_3, NH_2$ = anhydrous margarate of ammonia minus one equiv. of water.

Margaric ether. Syn. Margarate of oxide of ethyl. Form. $C_{34}H_{33}O_4, C_4H_5O$. (*Varentrapp.*) Solid, fusible at 72° .

Margarates. It is a contested point whether margaric acid is monobasic, for some chemists contend that in the formation of salts, sometimes both its equivalents of water and sometimes only one is replaced by another base. If it is bibasic, then its formula is $C_{68}H_{66}O_6 + 2HO$, and assuming the correctness thereof, the neutral alkaline salts, ($2M + C_{68}H_{66}O_6$), when in very dilute solution precipitate bimargarates. The earthy and metallic margarates are insoluble in water. The formulæ of the salts are as follows:—*bi-margarate of potassa* = $KO, HO + \overline{Mr}$; of the *neutral margarate*, $2KO + \overline{Mr}$; *margarate of lime* = $CaO + \overline{Mr}$; and *margarate of lead* = $2CaO + \overline{Mr}$, or according to Baudrimont, = $C_{34}H_{33}PbO_4$.

Margaryl. A hypothetical compound radical, $C_{34}H_{33}$, proposed by Redtenbacher as the basis of stearic and margaric acids, on account of the simple relation existing in their compositions. Thus, symbolizing it as R, stearic acid becomes $R_2 + O_5$ and margaric acid $R + O_3$, and here is the same relation between these two acids as between the sulphuric and hyposulphuric acids, with a slight difference however in their neutralizing ratios.

Gottlieb determined the fusing points of different mixtures of margaric and stearic acids, as follows:—

Stearic.		Margaric.		Fusing point.
30	...	10	...	150°
20	...	10	...	147.2°
10	...	10	...	136.4°
10	...	20	...	133.5°
10	...	30	...	132.8°

MARGARITE. See MICA.

MARGARITIC ACID. See CASTOR OIL.

MARINE ACID. Syn. Hydrochloric acid. See CHLORINE.

MARMATITE. See BLENDE.

MARMOLITE. See SERPENTINE.

MARROW. The fat oleaginous matter secreted in the interior of the bones of animals. The foreign matters, such as filaments, blood vessels, albumen, gelatin, and osmazome, with which it is more or less mixed, are removed by steaming, which melts the tallow and allows it to be drawn off clear from impurities which have subsided, or are retained in solution by the condensed vapor. In composition it is analogous to other fats, though it is probable that the olein and margarin are its predominant constituents. Beef marrow, used as a cosmetic for the hair, is of a bluish white color, and fusible at 113° .

MARTIAL ETHIOPS. The obsolete term for black oxide of IRON.

MARYGOLD. Geiger's analysis of the *Calendula officinalis* gave—

Yellowish green resin.....	3.44
Bitter extractive.....	19.13
Gum.....	1.5
Starch.....	1.25
Peculiar mucilage.....	3.50
Albumen.....	0.62
Free malic acid with bitter extractive	6.84
Malates of potassa and lime.....	7.92
Chloride of potassium.....	0.66
Lignin.....	62.5

MASONITE. *Min.* A dark gray, foliated mineral from Rhode Island, allied to hornblende or chloritoid. *C. T. Jackson.*

MASCAGNIN. *Min.* Crys. Rhombic, prismatic; usually efflorescent; yellow, translucent; taste pungent and bitter. Fusible and volatile; soluble in water; form. NH_4O , $\text{SO}_3 + 2$ or 1 HO . In lavas of Etna, Vesuvius, Lipari, &c.

MASOPIN. The name given to the dried sap of a tree called *Dschilte*, by the native Mexicans, who are said to chew it. Genth (*Ann. der Chem und Pharm.* xlv. 124,) has examined it. The sample was 9 inches in length, 4 inches in thickness, full of cavities and fissures, of a dull appearance, and light specific gravity. On cutting it with a knife, the surfaces of section were shining; the mass became soft between the fingers; it had scarcely any taste when chewed, but had a very decided smell of old cheese, which might be almost entirely removed by boiling in water; the residuous mass was soft, and might be drawn into threads; the water was somewhat colored, and had a slight acid reaction. Absolute alcohol dissolved the residue, with the exception of a small quantity of caoutchouc. On the cooling of the solution some white crystalline flakes separated, which might also be precipitated by the addition of water. It has therefore the properties of a resin.

Masopin is a light, snow-white, tasteless, inodorous powder, insoluble in water, easily soluble in ether, from which it crystallizes in white silky needles, which melt at 310°Fahr. , giving off an agreeable odor, to an amorphous mass. On cooling, it resembles glass, is of a wine-yellow color, of great refractive power, conchoidal fracture, and affords a white powder; its melting point is now only 158°Fahr. The substance crystallized from ether and melted, consists of $\text{C}_{22}\text{H}_{18}\text{O}$. Subjected to dry distillation, masopin affords a brown, thick, oily, acid mass, from which the acid may be removed by boiling with ammoniacal water. The oil, rectified over hydrate of lime, is of a light yellow color.

The acid is separated from the ammoniacal solution by hydrochloric acid in pearly scales; by combining it with lime, and decomposing the lime-salt with hydrochloric acid, they separate in the form of dazzling white needles. The acid affords with nitrate of silver and ammonia a white salt, which slowly becomes black by exposure to light, very quickly by boiling, is insoluble in water, and on incineration smells decidedly of cinnamon, leaving behind 45.49 per cent. oxide of silver; it is therefore probably cinnamate of silver.

Nitric acid has a very violent action on masopin, dissolving it after long boiling to a clear liquid, which on evaporation affords a tenacious mass, soluble in water of a yellow color, in ammonia and potash of a dark brown. The ammoniacal solution precipitates nearly all the metallic salts of a dirty white color. The silver salt contained 45.46—45.57 per cent. oxide of silver. An elementary analysis afforded 30.35 carbon and 3.37 hydrogen. The nitrogen has not been determined.

MASSICOT. Yellow protoxide of LEAD.

MASTICH. The resinous exudation of the *Pistacia lentiscus*. The two sorts are the mastic *in tears* and *common mastic*, the former being freer of foreign impurities. Spec. grav. 1.074. It consists of two resins, one of which is soluble in dilute alcohol, and of a slight portion of volatile oil.

Alpha resin. Formula $\text{C}_{40}\text{H}_{31}\text{O}_4$. Is the soluble acid resin which combines with bases to form four series of salts.

Beta resin. Syn. Masticin. Formula $\text{C}_{40}\text{H}_{31}\text{O}_2$. The elastic tenacious portion of mastic soluble in anhydrous alcohol, ether, and oil of terpentine. By long standing, in warm temperature, it also becomes soluble in weak alcohol.

MATICO. The pulverized dried leaves of a wild tree growing in the interior of Peru, on the other side of the Andes. Dr. Martins tested its efficacy upon open wounds, and with satisfactory success. The Indians assert that the fresh leaf has the power of instantaneously stanching a bleeding vein, and the beverage which they prepare from them they give to the women as an aphrodisiac.

Comp. Dr. Hodge's analysis gave chlorophyll, soft dark gum resin, brown and yellow coloring matters, gum and nitrate of potassa, a bitter principle (*maticin*), an aromatic volatile oil, salts, and lignin.

Volatile oil. Light green, thick and heavy, with an aromatic and camphory taste. By keeping, it becomes crystalline.

MATTRASS. A flask-shaped, broad-bottomed vessel of glass, free from lead and blown thin, so as to withstand sudden expansion and contraction without breaking. They are used for digesting substances, especially with acids, as the menstruum.

MAYNAS RESIN. So called from its place of derivation, Maynas in America. It is obtained by incision from the *Calophyllum calaba*. Is yellow and in appearance similar to other resins; but, according to Lewy, it separates from a slowly-cooled alcoholic solution in beautiful yellow crystals. Their formula is $\text{C}_{14}\text{H}_9\text{O}_4$, and they have acid properties and combine with the bases. Spec. grav. 1.12; fusing point 221° . It is insoluble in water, but very soluble in alcohol, ether, the oils, and in cold acetic and sulphuric acids, from the latter of which it is precipitated unaltered by water. Fuming nitric acid acts violently, and from the solution, water throws down a yellowish white nitrogenous uncrystallizable acid, soluble in alcohol and ether. Digested with nitric acid of 1.31, it yields red vapors, a liquid, and volatile acid, (with all the characters of butyric acid,) oxalic acid, and a crystalline acid, soluble in water and wanting the property of precipitating salts of lime.

MEADOW SAFFRON.

MEADOW SAFFRON. See COLCHICUM.
MEASURES. See WEIGHTS AND MEASURES.
MECCA BALSAM. See OPOBALSAMUM.
MECHLOIC ACID. See MECONIN.

MECONIC ACID. *Chem.* $C_{14}H_{11}O_{11} + 3HO + 6aq$. Obtained from opium in pearly scales, of an astringent, acid taste, soluble in hot water and alcohol. By boiling, it is decomposed into carbonic and comenic acids, and other products. Hydrochloric acid facilitates this change. By contact with alkaline lyes, it is transformed into alkaline carbonate and oxalate. Its characteristic property is that of reddening the persalts of iron. When heated, it yields, among other matters, *comenic, pyromeconic, and paracomenic acids*. With bases it forms three kinds of salts, according as 1, 2, or 3 equiv. of the hydratic water are replaced by metallic oxides. The general formulæ for these salts are:—

Monobasic Salts.	Bibasic Salts.	Tribasic Salts.
$\overline{Me} \begin{cases} MO \\ 2 HO \end{cases}$	$\overline{Me} \begin{cases} 2 MO \\ HO \end{cases}$	$\overline{Me}, 3 MO$

Comenic acid. $C_{12}H_2O_8 + 2HO$. Formed as above, at 250°, or by prolonged action of boiling acidulated water upon meconin. It is in very hard crystalline grains, slightly soluble in water, and when heated to 570° it is decomposed into pyromeconic acid.

Paracomenic acid. Is isomeric with comenic acid, and forms the last portions of the distillate of that substance. It crystallizes, and behaves to the persalts of iron in the same manner as comenic acid.

Pyromeconic acid. $C_{10}H_3O_5 + HO$. Drops from its alcoholic solution in long colorless prisms, which darken on exposure to moisture. It is also soluble in water, and though it crystallizes unaltered from alcoholic solution of potassa, and from aqua ammonia, yet forms definite compounds with the oxides of lead, copper, and iron. Is isomeric with pyromucic acid, but differs from it in properties.

MECONIN. *Chem.* $C_{10}H_7O_4$. Is extracted from opium, and forms white hexagonal prisms, which are neutral, acid to the taste, and without action upon the animal economy. It fuses at 194°, and distils unaltered at 311°, is soluble in water, alcohol, ether, essential oils, HCl, acetic and dilute sulphuric acids, and insoluble in ammonia. Its compound with chlorine, called *mechloic acid*, $C_{14}H_7O_{10}$, crystallizes in pearly plates, soluble in boiling water, in alcohol, and ether, melting at 320° and subliming at 330°. *Nitro-meconin*, $C_{20}H_9O_9 + NO_3$, resulting from the action of nitric acid, crystallizes in white prisms, soluble in alkalies, with a red color, in water and alcohol. It melts at 305° and sublimates at 375°, giving off the odor of bitter almonds.

MEDULLIN. The pith of certain plants. In chemical properties it agrees with cellulose or LIGNIN.

MEERSCHAUM. Several hydrous silicates of magnesia are doubtless included under this name, and others have been examined, allied to it. They are white, or yellowish, very light, earthy, and friable, greasy to the touch; and from their porosity include more water than belongs to their composition. Their proper composition is probably $MgO, SiO_3 + 2HO$;

MELLITIC ACID.

but it is also probable that there are other magnesian minerals, described as meerschaum, which have merely its external characters; such as aphrodite from Långbanshyttan, Sweden, $3MgO, 2SiO_3 + 2HO$; quincite, magnesite, &c.

MEIONITE. See SCAPOLITE.

MELACUPRITE. *Min.* Melaconin, black oxide of copper more or less mixed with oxide of iron, of which tolerable specimens are found at Point Kewaywenon, Lake Superior.

MELAM. See CYANOGEN.

MELAMIN. See CYANOGEN.

MELAMPYRIN. Crystallizes from an evaporated aqueous decoction of the *Melampyrum nemorosum*. A non-azotized, neutral, colorless body, insoluble in ether, slightly soluble in alcohol, but readily in water, from which latter the metallic compounds do not precipitate it.

MELANCHOR. *Min.* A black phosphate of iron from Rabenstein. See GREEN IRON STONE.

META GALLIC ACID. } See GALLIC ACID.

MELANGALLIC ACID. }

MELANIC ACID. See SALICULE.

MELANITE. See GARNET.

MELANOCHROITE. *Min.* Cryst. Rhombic, prismatic; in tabular plates, and massive. Very soft; $G. = 5.75$. Cochineal-red, with brick-red streak; resinous and glimmering; subtranslucent, opaque. It becomes dark by heat, and fuses to a crystalline mass, giving the reaction of lead, and with the fluxes those of chrome. Soluble in muriatic acid. Form. $3PbO, 2CrO_3$. It is associated with chromate of lead at Beresovsk, Ural.

MELASSIC ACID. See GRAPE SUGAR.

MELLITE. See HONEY-STONE.

MELLITIC ACID. *Chem.* Obtained from honey-stone, a rare mineral, in which it exists as mellitate of alumina. Erdmann and Marchand's recent researches (*Journ. für Prakt. Chem.* xliii. 129) have confirmed Liebig and Wöhler's formula, C_4O_3 .

Prep. Digest the honey-stone in carbonate of ammonia, and separate the solution from the deposited alumina by filtration. The crystals forming from the filtrate are to be boiled with an excess of baryta, the baryta separated by sulphuric acid, and the acid purified from adherent oil of vitriol by recrystallization.

Prop. Forms white acicular crystals, soluble in alcohol and water. Its alkaline salts are soluble and crystallizable, but those with other bases are less so than the former. With potassa and ammonia it unites in two proportions. The general formula for the neutral salts is MO, C_4O_4H . Schwartz was unable to obtain a mellitic ether, but Erdman and Marchand procured *mellitovinic acid*, $C_4H_5O, 2C_4O_3$, by long continued boiling of a mixture of the acid with alcohol and oil of vitriol. By heating the mellitate of ammonia to 320°, ammonia and water are given off, and *euchronic acid* and *paramide* remain. *Chem. Gaz.* vi. 323.

Euchronic acid. A conjugate mellitic acid, which, when crystallized, is $C_{12}NO_6, 2HO$. The dark blue substance resulting from the deoxidation of euchronic acid by a plate of zinc, Wöhler calls *euchrone*, $NH_3 + C_4O_4H$, and assumes that it is a similar compound to colorless indigo, and the colorless or green hydroquinone produced by the assimilation of hydrogen.

Paramide. A clay-like yellow solid, C_6HNO_4 , which, by long ebullition in water, is transformed into bi-mellitate of ammonia by the assumption of 4 equivs. of water.

MELLON. } See *Mellan* under Sulpho-
MELLAINDES. } CYANOGEN, p. 512.

MENACHANITE. See TITANIFEROUS IRON.

MENACHINE. See SPHENE.

MENIFFITE. *Min.* Berzelite, kerasite. Cryst. Right rhombic, fibrous, columnar. $H. = 2.5 - 3$, $G. = 7 - 7.1$. White, yellowish, reddish; pearly; translucent, opaque. Behaves like corneous lead, but decrepitates by heat; if added to a bead of mic. salt, containing oxide of copper, the blue color of the flame indicates chlorine; soluble in nitric acid. Form. $PbCl + 2 PbO$. It occurs at Mendip Hills, Somersetshire.

MENGITE. See MONAZITE.

MENILITE. See OPAL.

MENISPERMIN. See COCCULUS INDICUS.

MENSTRUUM. The liquid employed as the solvent of a body, or of its soluble portions. See SOLUTION.

MENTHEN. See PEPPERMINT.

MEPHITIC ACID. See CARBOXY ACID.

MERCAPTAN. See ETHYL.

MERCURY. *Min. Ger.* Gediengen Quecksilber. It occurs in small fluid globules, with a silvery metallic lustre, scattered through mercurial ores, at Almadin, Spain; Idria in Carniola; in Carinthia, Hungary, Peru, Chili, California, China, &c.

MERCURY. *Chem. Tech.* Syn. Quicksilver. *Gr.* $\delta\gamma\alpha\gamma\gamma\epsilon\varsigma$. *Lat.* Hydrargyrum, argentum vivum. *Ger.* Quecksilber. Known from very early times. Plinius states that the Greeks imported cinnabar from Almaden, in Spain, 700 years B. C., and in his time the Romans used annually some 300 tons from the same source. These mines at the present time yield about one-half of all the rest in the world. Mercury occurs almost exclusively as sulphuret, small quantities being found native, and as chloride, and in a few sulphuretted minerals.

EXTRACTION OF MERCURY.

From its volatility, it is always obtained by distillation; and to separate the sulphur, lime or smithy slack (oxide of iron) are used. The first method, now abandoned, consisted of an earthen vessel, which was filled with ore and lime, closed at the top, placed over another, probably buried in the ground, and then heated by a fire built around it. The vapors passed down through perforations in the bottom of the upper into the lower vessel, where they condensed.

In the Palatinate, on the Rhine, a *gallery* furnace is used, consisting of cast iron cucurbits or flasks, 30 to 50 of which are laid horizontally in two tiers in the open furnace, their necks projecting beyond both of the side-walls and fitting into earthenware receivers. Each cucurbit holds about $\frac{1}{2}$ cwt. ore, which is mixed with $\frac{1}{4}$ or $\frac{1}{5}$ its volume of lime, previously dry slacked.

The arrangement adopted at Almaden, in Spain, probably introduced by the Moors, consists of a high furnace with a fireplace below, surmounted by a perforated arch. Above this arch the ores are piled up, the larger and

poorer masses lying on the arch, above which are smaller ores, and at the top bricks made of clay and ore. The smoke, hot air, &c. of the fire, passing through the ores, carry up with them the mercury, and all then pass through a lateral opening in the top of the furnace, and through the aludels. These are pear-shaped earthen vessels, similar to the straight adopter, fig. 7, p. 46, arranged in series, the narrow neck of one fitting into the wider end of the next. Several of these ranges descend from the opening in the furnace on a slightly inclined plane, and rise again to a tower, in which the fumes descend to the lowest point, and rising pass out at the top. The greater part of the mercury is condensed in the descending ranges of aludels, the lowest one in each series being perforated to allow its escape. Some condenses in the rising ranges, and most of the balance is collected in the tower. The apparatus is not at all economical, for there is a danger of loss at every junction of the aludels, which are very numerous.

The arrangement at Idria is a modification of that of Almaden. It consists of a central furnace, with condensing chambers on two opposite sides. The furnace has a grate below for the fuel, and above it are arched floors to contain the prepared ore. The vapors pass through a long series of chambers vertically, upward and downward, and finally escape, all or nearly all the mercury having condensed. Although superior to the aludel plan, it is much more costly than necessary in apparatus, and not convenient in use.

The best method of distilling mercurial ores is in cast iron retorts, arranged like gas-retorts, in benches, and collecting the metal in iron pipes. The retorts are easily charged and cleaned, and economize labor, fuel, and mercury.

The principles involved in the extraction of mercury are simple. The sulphuret may be sublimed unaltered, but if the air have access, more or less of the sulphur burns to sulphurous acid, and the metal is set free. But it is more advisable to mix a base with the ore, which shall seize the sulphur. Lime is that most anciently employed, and is still used; it forms by the process, sulphuret of calcium and some sulphate of lime. Oxide of iron forms sulphuret of iron and sulphurous acid. Metallic copper is very efficient, especially as it forms a fusible sulphuret of copper; but it has received as yet little attention. The quantity of mercury produced annually in the world is about 2000 tons, of which the Spanish mines furnish more than one-half.

MERCURY AND ITS NON-SALINE COMPOUNDS.

1. *Mercury.* The commercial metal is more or less impure. It may be purified by redistillation with a covering of iron filings, with $\frac{1}{10}$ its weight of cinnabar, in vessels of iron, glass, or earthenware; or by distillation of the red oxide, which is the best method. To determine its purity, it may be oxidized by nitric acid and distilled without a residue.

Prop. A fluid metal of a bright silvery lustre, not tarnishing in the air, when pure, but forming a gray oxidized dross on the surface, if alloyed with other metals; spec. grav. 13.5886 at 39.2°, 13.5569 at 62.6°, 13.535 at 78.8°.

MERCURY.

At -39° it congeals to a tough crystalline solid, or regular 8-hedra, malleable and sectile, with a calculated spec. grav. 14.39. It expands by heat with great uniformity until near its boiling point, which is about 680° ; spec. grav. of its vapor 6976; it volatilizes, however, far below its boiling point, and at common temperatures, and even near 32° . It is readily attacked by nitric acid, chlorine, &c., and forms two oxides with their salts. All its compounds are volatilized or decomposed by heat, and yield metallic mercury by distillation with carbonate of soda or cyanide of potassium. Sym. Hg. Eq. 100, (1265.823, O. = 100, or 101.266, H = 1. Berz.) Swanberg's late determination of the equiv. gives it as most probable 1250.9 or 100.07.

2. *Oxides. a. Suboxide.* Black or protoxide. Ger. Quecksilberoxydul. Prep. By treating a salt of suboxide (calomel) by caustic alkali, washing and drying. It is a brownish black powder, decomposing by light or warmth into oxide and metal, giving a portion of its oxygen to potassium, and its iodide, phosphorus acid, &c. with other agents changing into oxide and metal.

Salts. The black oxide is a feeble base, its salts are formed by solution of the suboxide in acids, by the action of nitric and sulphuric acids on the metal and by precipitation. The salts are colorless, the basic yellow, generally soluble, with metallic taste, some decomposing by water into a basic and an acid salt; the insoluble are mostly soluble in nitric acid. They are decomposed, yielding the metal, by many of the metals, phosphorus, charcoal, sulphurous acid, and the protosalts of iron and tin, and by some organic substances, especially if heated. Caustic alkalies precip. black oxide, carbonate of potassa yellow, bicarbonate white, blackening by heat; precipitable by the earthy carbonates; phosphate of soda, oxalic, muriatic, and bromohydric acids, soluble chlorides and bromides, and yellow prussiate of potash give white precipitates; iodohydric acid and iodides green, chromate of potassa brick red, red prussiate, brownish red, changing to white, galls brownish yellow; sulphuretted hydrogen, sulphhydrates, and dithionites black sulphuret.

b. Oxide. Red oxide, red precipitate, deutoxide. Ger. 2. Oxyd. Prep. By heating the nitrate mixed with a little mercury until nitrous fumes cease to rise, or by precipitation from a salt, with excess of potassa.

Prop. A light red crystalline or earthy powder, or by precip. orange-colored; becomes dark red and almost black by heat, and is resolved into oxygen and metal, both distilling off; decomposed by potassium, phosphorus, sulphur, &c., explosively if heated with the last; scarcely soluble in water with alkaline reaction. Form. HgO, containing 92.59 pr. ct. mercury and 7.41 oxygen.

Salts. The salts of this oxide are much more important than those of the black oxide, and are formed similarly, but those with nitric and sulphuric acids acting on the metal are made by heat. They are colorless, (yellow, if basic,) redden litmus, have a metallic taste, and are very poisonous. The metal is reduced from them by the same substances as from the salts of the black oxide. Caustic fixed alkali gives an orange precipitate of anhydrous oxide,

MERCURY.

but if organic substances be present, black oxide results; carbonated alkalies give a brownish red precipitate; caustic and carbonate of ammonia a white, visible in 20,000 pts. water, and hence the presence of ammonia gives a white precipitate with fixed alkali; the carbonated alkaline earths precipitate the salts; a white precipitate is produced by phosphate of soda and prussiate of potassa; yellow by nut galls; orange-red by chromate of potassa; brilliant red by iodide of potassium; black by sulphuretted hydrogen and an excess of sulphhydrates, but with less of the latter, white.

3. *Sulphurets. a. Subsulphuret*, Hg₂S, formed by the action of a sulphhydrate on calomel; is black, and readily decomposes into metal and sulphuret.

b. Sulphuret. Syn. Cinnabar, vermilion. Ger. Zinnober. The black is called also Ethiops' mineral. Form. HgS, containing 86.21 pr. ct. mercury. It occurs native as CINNABAR.

Prep. It may be made both in the wet and dry way. *Dry method.* The Dutch fuse 50 lbs. sulphur in a cast iron vessel at a low heat, and gradually stir in, with an iron ladle, 170 lbs. mercury, and cast it on an iron plate. It is broken into pieces, a few pint measures of which are thrown into heated cylinders of earthenware, glazed internally, of 4 ft. height, a number of which are placed in a common furnace; when the flame of burning sulphur ceases, a smooth iron plate is laid upon the top of the cylinders, and when sufficient cinnabar has deposited, it is removed and replaced by another plate. It is then ground very fine with pure water. The Chinese method is somewhat similar, the sublimation being conducted in earthen vessels covered with an iron cap, which is cooled by water during the operation.

The process pursued in Idria consists in mixing 8 lbs. sulphur with 42 lbs. mercury, in barrels, and turning them for several hours, according to the season, until the whole forms a brown powder. 100 lbs. of this powder is thrown into a heated cast-iron cylinder, placed vertically in the furnace, and the cylinder covered by a heavy iron helm or cap, until the explosive union has taken place. It is then replaced by an earthen helm, with a cooling tube attached, and the fire increased; the best sublimate is removed from the helm, ground with cold water, washed with hot.

Wet method. 100 pts. mercury are rubbed for several hours with 33 pts. flowers of sulphur to black sulphuret, and then warmed in a solution of 25 pts. potassa in 140 pts. water at 113° to 120° , under constant stirring at first, and occasionally afterwards. The evaporating water is replaced from time to time. When the change commences the heat is not allowed to rise above 113° , and as soon as the red has attained its greatest brilliancy, the vessel is removed from the fire and maintained for some time at a gentle warmth. It is then washed, and the metallic mercury separated. The product should be 109 or 110 pts. vermilion. Various other proportions may be employed. If by too long or too high a heat the vermilion has passed the brilliant red and become brown, it may be restored by warming it with water.

Adulterations of vermilion are recognised:

red lead by leaving fused litharge by heat, or forming chloride of lead by the action of muriatic acid; brick-dust by remaining after heating; organic colors may generally be extracted by alcohol.

The black sulphuret is formed by rubbing the metal and sulphur, or sulphuretted alkali together, or by precipitating a solution of oxide by sulphuretted hydrogen or sulphuretted alkali. Warmth, the addition of sugar or a little alkaline sulphuret, hastens the sulphuration.

There appears to be no difference between the black and red sulphuret in composition; by heating vermilion above 350° , it becomes brown, but becomes red again on cooling; by heating it to about 500° , it becomes permanently the black sulphuret; by heating the black sulphuret still higher, it sublimes as vermilion.

Water, alkali, and muriatic acid do not act on vermilion. Nitric acid has but a slight action on it. Boiling oil of vitriol and aqua regia wholly decompose. By heating it with several metals, caustic and carbonated fixed alkali, or by cyanide of potassium, the metal sublimes from it.

4. *Phosphuret* of mercury is formed by digesting 4 pts. mercury and 3 pts. phosphorus with water, or by passing phosphuretted hydrogen over dry, slightly-heated chloride of mercury. In the former case it is black, in the latter orange-yellow phosphuret sublimes.

Hyposulphophosphite, HgS , PS , is formed by heating sulphuret of phosphorus with vermilion, as a reddish mass. By heating this salt to about the boiling point of sulphur, mercury sublimes, and the yellowish white sulphophosphite remains: 2HgS , PS_3 . By heating this last in the retort, it is resolved into mercury and yellow sulphophosphate, 2HgS , PS_5 , which sublimes, and at a higher heat sub-hyposulphophosphite, 2HgS , PS , also sublimes of a brilliant red color.

5. *Nitruet*. NHg_3 . Precipitate red oxide of mercury, wash, dry, put it into a tube and pass ammonia over it to saturation; then heat it gradually in an oil-bath, while ammonia still passes over, up to 300° , as long as water is generated. A dark brown powder, highly explosive by heat, stroke, or friction.

6. *Amalgams*. The alloys of mercury with other metals, termed amalgams, are of a peculiar character, since they permit us to examine the nature of fluid alloys at common temperatures. Amalgams are made by bringing the metals together in the cold rapidly, as with potassium, sodium, gold, lead, cadmium, tin; more slowly with silver, zinc, bismuth; by heat with antimony and arsenic; by the intervention of a solution of nitrate of mercury with copper; by the use of sodium-amalgam put in solutions of nickel, cobalt, platinum, iridium, the metals of the alkaline earths, aluminum, and ammonium. The fluid amalgams are semi-solutions of a more solid amalgam in excess of mercury, from which the latter may be separated by pressing through buckskin. These more solid amalgams are crystalline, and so soft as to be capable of being kneaded. A small amount of mercury in another metal increases in general its fusibility, and imparts to it brittleness.

Uses. Mercury is largely employed in the extraction of gold and silver; tin amalgam for covering the backs of mirrors; chloride of mercury in various arts; and vermilion as a color. It is an invaluable metal for physical research, in the thermometer, barometer, &c., and its compounds are of great interest to the chemist.

HALOID SALTS.

1. *Chlorine. Subchloride of Mercury*. Syn. Protochloride, di-chloride, hydrargyri, submurias, calomel. It is found native as Horn Quick-SILVER. Form. Hg_2Cl_2 , containing 85 pr. ct. mercury.

Prep. It is obtained by rubbing together 4 pts. corrosive sublimate with 3 pts. mercury, while moistened with water or alcohol, until the metal disappears, and subliming the mixture. A mixture of equal parts of common salt and subsulphate of mercury may be similarly sublimed. Precipitated by chloride of sodium from the solution of nitrate of mercury, it takes the form of a white powder containing more or less of corrosive sublimate, on account of the difficulty of obtaining the nitrate in a perfect proto state. On a large scale it is procured by sublimation from a well-triturated mixture of 272.84 pts., or 1 equiv. of the bichloride with 202 pts., or 1 equiv. of metallic mercury. (*Turner*.) The size and temperature of the receiving vessels has an important influence upon the form in which the calomel is obtained. As sublimed in shallow iron pots, lined with clay, it is in crystalline masses, which, after the separation by hand of the globules of uncombined metal, is ground to powder in a mill, and then washed of its impurities by frequent aqueous elutriations. Jewell's method does away with the use of a mill, for by bringing the vapors of the calomel in contact with steam at the moment of their generation, they are immediately condensed in a roomy chamber, to an impalpable powder of brilliant whiteness. Soubeiran's improvement upon this plan consists in heating the calomel in an earthen tube, through which, by means of small ventilators, an uninterrupted current of air should be driven. This sweeps away, as it were, the vapors of calomel, and in a straight tube will carry them to a distance of 60 feet, to avoid which, the end of the recipient must dip into cold water, that the calomel may be moistened, and then settle. Rhighini's assertion, that long-continued contact with steam transforms a portion of the vapory calomel into corrosive sublimate, is of no serious hindrance in large practical operations, because whichever way prepared, it is necessarily to be well washed with water, to free it of that and other impurities, before being sent to market.

A buff color indicates its freedom from bichloride, though a white shade by no means infers the presence of that salt. Its spec. grav. is 7.2. It is decomposed by contact with many of the metals, by heating with sulphur and some sulphurets; by heating with oil of vitriol strong nitric and muriatic acids; by subliming with salammoniac, or boiling with its solution, the tendency in all these decompositions being to form chloride of mercury. In a solution of potassa or soda it forms black suboxide, and by heating with the dry alkalies it yields the

metal; under caustic ammonia it forms black subchloramide of mercury, $\text{Hg}_2\text{Cl} + \text{Hg}_2\text{NH}_2$. A sulpho-subchloride is formed by mixing well 94 pts. corrosive sublimate with 6 pts. flowers of sulphur, and gently heating the mixture; after some minutes, crystals effloresce on the surface of the composition, $\text{Hg}_2\text{Cl} + \text{SCl}$. Stanno-subchloride is made by fusing 3 tin and 1 mercury together, mixing this with 24 pts. calomel, and heating in a retort at 480° . By breaking the retort, draining out metallic mercury, and distilling the residue at 570° , a salt sublimes with the form. $\text{Hg}_2\text{Cl} + \text{SnCl}$.

Chloride. Syn. Corrosive sublimate, Bichloride. Form. HgCl , containing 73.86 pr. ct. mercury. Spec. grav. 5.42. Crystallizes in opaque rhombic prisms, from a solution of red oxide of mercury or calomel in hydrochloric acid. The exact proportions required for its production by double decomposition are 148 pts. (1 equiv.) sulphate of the peroxide of mercury to 58.5 pts. (1 equiv.) chloride of sodium. But it is usually prepared by subliming equal parts dry sulphate and common salt; or 10 pts. mercury, 8 pts. common salt, 6 pts. binoxide of manganese, 11 pts. oil of vitriol, and 3 pts. water.

It is fusible and volatile at about 500° . 100 pts. water, at 32° , dissolve 5.73 pts. of this salt; at 50° , 6.57 pts.; at 68° , 7.39; at 104° , 9.62; at 140° , 13.86; at 176° , 24.3; and at 212° , 53.96 pts. It is also soluble in $2\frac{1}{2}$ pts. of cold, and $1\frac{1}{2}$ hot alcohol; in 3 pts. cold ether, and in the essential oils. As it forms double salts with the alkaline chlorides, their addition and that of muriatic acid to water facilitates its solution in that liquid. The brown precipitate thrown down by potassa from a solution of corrosive sublimate, and which by boiling becomes black and crystalline, is an *oxychloride of mercury* ($\text{HgCl} + 3\text{HgO}$), and can be as readily formed by boiling red oxide of mercury in a solution of chloride. Vegetable and animal albumen have heretofore been the most efficient antidote to the virulence of corrosive sublimate, by forming a white, flocculent, insoluble precipitate, and hence the use of white of eggs in cases of poisoning by this salt. Latterly, Mialhi has given the preference to the moist, recently precipitated sulphuret of iron, which immediately decomposes the minutest trace of chloride of mercury.

Corrosive sublimate boils at about 563° , and the spec. grav. of its vapor is 9420, 1 vol. of it containing 1 vol. mercurial vapor and 1 vol. chlorine gas. Exposed to the rays of the sun, oxygen is evolved from its solution, while HCl is dissolved, and the subchloride of mercury precipitates.

It is easily decomposed by several metals, by sulphur, phosphorus, and their lower acids. An excess of sulphuretted hydrogen or sulphuretted alkali throws down black sulphuret; too little of these reagents, and many metallic sulphurets produce a yellow precipitate, changing to white of sulphochloride of mercury. Heated with caustic or carbonated fixed alkali, it is partly resolved into metal, and the caustic in solution precipitates red oxide; caustic ammonia throws down white chloramide.

Chloride of mercury and ammonia. Into a boiling solution of salammoniac, containing

ammonia, drop a solution of chloride of mercury as long as the precip. redissolves by stirring. It crystallizes on cooling in 12-hedra of the form. $\text{HgCl} + \text{NH}_3$. By heating the latter gently it loses ammonia, becoming $2\text{HgCl} + \text{NH}_3$, which may be fused and sublimed. Another compound, *white precipitate*, is obtained by dissolving equal pts. salammoniac and corrosive sublimate in boiling water, and precipitating the cooled, clear solution by carbonate of soda. Its form. is either $(2\text{HgCl} + \text{HgO}) + \text{NH}_4\text{Cl}$ (*Duflos*), or $3\text{HgCl} + \text{NH}_3 + \text{HO}$. It is fusible, boils, and yields water and ammonia.

Chloramide of mercury is formed by adding ammonia to a solution of corrosive sublimate as long as a precipitate is produced; it is white, and insoluble in water; does not fuse below 680° , which distinguishes it from white precipitate. Its formation is $2\text{HgCl} + 2\text{NH}_3 = \text{HgCl} + \text{HgNH}_2 + \text{NH}_4\text{Cl}$.

Chloride and nitruet of mercury. The preceding chloramide is dried, and very slowly heated in a retort in a metallic bath to 680° , so that ammonia and ammonia chloride of mercury sublime, and the new compound remains in the form of red scales, which are insoluble in water, and may be heated in a solution of potassa, in strong nitric, or dilute sulphuric acid without change. Form. $2\text{HgCl} + \text{Hg}_3\text{N}$.

Chloramide and oxide of mercury is produced by boiling chloramide with water, as a yellow powder with the form. $(\text{HgCl} + \text{HgNH}_2) + 2\text{HgO}$.

Sulphochloride of mercury is formed when a small amount of sulphuretted hydrogen is passed into a solution of corrosive sublimate, or by digesting freshly precipitated sulphuret of mercury in a solution of chloride. A white powder, not decomposed by boiling water, sulphuric, nitric, or muriatic acid; decomposed by alkalies forming oxysulphuret of mercury and alkaline chloride. Form. $\text{HgCl} + 2\text{HgS}$. The same salt with sulphochloride of copper ($\text{HgCl} + 2\text{HgS} + (\text{HgCl} + 3\text{CuS})$) is obtained by putting fresh sulphuret of mercury in a concentrated solution of chloride of copper; an orange yellow powder.

Chloride and phosphuret of mercury, $3\text{HgCl} + \text{Hg}_3\text{P} + 3\text{HO}$, is obtained by passing phosphuretted hydrogen into the chloride as long as a precipitate occurs; the dark precipitate of phosphuret changes to yellow, and must be dried in vacuo.

Chloride and arseniuret of mercury is formed by rubbing together 3 pts. chloride of mercury and 1 pt. metallic arsenic, and subliming the mixture from a retort in a sand bath. The outer layer of the distillate consists of yellow crystals, the salt in question. The inner brown layer, resublimed with arsenic, gives a red, in mass a brown sublimate, with yellow powder, which is probably a similar body.

Double salts, with other metallic chlorides, are obtained by directly mixing the solutions and allowing to crystallize spontaneously. The salt of potassa, $\text{KCl} + 2\text{HgCl}$, crystallizes with 1, 2, or 4 equivs. HO , according to concentration and temperature; that of soda with 4 HO . The salt of ammonia, $\text{NH}_4\text{Cl} + \text{HgCl} + \text{HO}$, was formerly termed salt of Alembroth;

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according to Kane, there are also salts, $\text{NH}_4\text{Cl} + 2 \text{HgCl}$, with and without 1 HO. The salt of baryta is $\text{BaCl} + 2 \text{HgCl} + 4 \text{HO}$, efflorescent; of strontia, $\text{SrCl} + 2 \text{HgCl} + 2 \text{HO}$, permanent; of lime, $\text{CaCl} + 5 \text{HgCl} + 8 \text{HO}$, which is resolved by cold water into $\text{CaCl} + 2 \text{HgCl} + 6 \text{HO}$, both deliquescent; of magnesia, $\text{MgCl} + 3 \text{HgCl} + \text{HO}$, and $\text{MgCl} + \text{HgCl} + 6 \text{HO}$, both deliquescent; of lithia, yttria, glucina, and cerium, not examined; of manganese, $\text{MnCl} + \text{HgCl} + 4 \text{HO}$ and zinc, in which an excess of chloride is dissolved, crystallizes in large crystals; of iron, $\text{FeCl} + \text{HgCl} + 4 \text{HO}$, and of cobalt, nickel, and copper, the last permanent in the air; of acetate of copper, $2 \text{CuO}, \text{AcO}_3 + 2 \text{HgCl}$, deep blue; of potassium and copper, $3 (\text{KCl}, \text{HgCl}) + \text{CuCl} + 2 \text{HO}$.

2. *Bromine. Subbromide.* Hg_2Br . Is a white powder, precipitated by an alkaline bromide from subnitrate of mercury. It resembles calomel in nearly all its relations, and forms a black subbromamide with caustic ammonia, $\text{Hg}_2\text{Br} + \text{Hg}_2\text{NH}_2$; it also forms a double salt with strontia, $\text{SrBr} 2 \text{Hg}_2\text{Br}$, which is resolved by water into $\text{SrBr} + \text{Hg}_2\text{Br}$.

Bromide. Syn. Bibromide, deutobromide. Obtained by treating mercury or its subbromide with bromine and water, forms colorless, soluble crystals; it fuses, sublimes, is soluble in water and alcohol, and distinguished from chloride by not precipitating with chromate of potassa. The oxybromide is similar to the oxychloride and similarly made; form. $\text{HgBr} + 3 \text{HgO}$. The bromide absorbs ammonia, forming $2 \text{HgBr} + \text{NH}_3$, white, insoluble, sublimable. The nitret, bromamide, sulphobromide, and phosphobromide are like the corresponding chloride compounds. The bromide also forms a class of double salts, with the alkalies, alkaline earths, and metals, similar to those of the chloride.

3. *Iodine. Subiodide* is prepared by triturating thoroughly 200 pts. mercury with 126 pts. iodine, moistened with a little alcohol, and extracting free iodine with warm alcohol; it is a yellow powder, very easily decomposed by light.

Iodide is obtained either directly by triturating 100 pts. mercury and 126 iodine, or by precipitating a salt of red oxide by an alkaline iodide; and in crystals by dissolving it in a moderately strong boiling hot solution iodide of potassium to saturation, and suffering it to cool; or again by dissolving iodine in a boiling solution of nitrate of mercury to saturation, constantly replacing the evaporating water. It is scarlet-red, spec. grav. 6.2 — 6.32; fusible to a yellow liquid, which congeals to a yellow, crystalline mass, and sublimes as yellow crystals, and by care with red crystals among the yellow. The red may be changed to yellow below the temperature of fusion, and the yellow may be changed to red by slight causes at ordinary temperatures, as by contact of a point, from which the change spreads with molecular movement through the whole mass. The red crystals are quadratic, the yellow right rhombic.

A *biniodide* is said to be obtained by precipitating chloride of mercury with biniodide of potassium as a black powder. The iodide with

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oxide, with sulphuret, with amide, and oxide and amide are similar to the chloride compounds. It forms a class of double salts, corresponding to the chloride, some of which tend to pass from yellow to red like the iodide itself. It also unites with chlorides forming double salts.

4. *Fluoride*, HgF , is obtained by pouring fluohydric acid over red oxide of mercury, which changes to an orange yellow powder, soluble in water, and crystallizing from its solution; it attacks glass and platinum. By passing sulphuretted hydrogen into this solution, a sulphofluoride is thrown down as a white powder. $\text{HgF} + 2 \text{HgS}$. The fluoride of mercury and ammonium is a white insoluble powder.

OXYSALTS.

A. *Salts of black oxide*, Hg_2O . 1. *Sulphate*, $\text{Hg}_2\text{O}, \text{SO}_3$ obtained by carefully heating 1 pt. mercury with 1 or $\frac{3}{4}$ pt. oil of vitriol to the point of gas evolution, ceasing the operation when it is changed into a white powder; it is rinsed with a little cold water. It crystallizes from a solution in boiling water, or better from a hot solution in dilute sulphuric acid. It may be also obtained by subliming the sulphate of the red oxide. Soluble in 500 pts. cold and 300 boiling water. The *sulphate with amide*, $\text{Hg}_2\text{O}, \text{SO}_3 + \text{Hg}_2\text{NH}_2$, is obtained as a dark gray powder by pouring ammonia over the sulphate; if heated in ammonia, it adds 2 Hg_2O to this double salt. *Dithionate* of mercury, $\text{Hg}_2\text{O}, \text{S}_2\text{O}_5$, is obtained by dissolving freshly precipitated oxide in hyposulphuric acid, and crystallizing by gentle evaporation; soluble in nitric acid, decomposed by boiling with water. *Dithionite* is obtained in combination with copper by mixing dithionite of mercury and potassa with blue vitriol; the brownish red salt has the form. $3 (\text{Hg}_2\text{O}, \text{S}_2\text{O}_2) + 5 (\text{Cu}_2\text{O}, \text{S}_2\text{O}_2)$.

2. *Nitrate* is obtained by dissolving mercury in an excess of cold nitric acid, from which it crystallizes in colorless crystals, with the form. $\text{Hg}_2\text{O}, \text{NO}_5 + 2 \text{HO}$; decomposed by much water into a more basic, and by still more water into a more basic salt. If an excess of metal be treated with cold dilute nitric acid, a basic salt is obtained in colorless prisms, with the form. $3 \text{Hg}_2\text{O}, 2 \text{NO}_5 + 3 \text{HO}$. If either of these nitrates be treated with much water, hot or a little alkaline, until the liquid ceases its acid reaction, a yellow powder remains, of the composition $2 \text{Hg}_2\text{O}, \text{NO}_5 + \text{HO}$. A basic salt with ammonia is obtained by precipitating the neutral salt with ammonia, and is known as Hahnemann's soluble mercury; form. $\text{Hg}_2\text{O}, \text{NO}_5 + \text{Hg}_2\text{O}, \text{NH}_3$. A basic *nitrite* is obtained by continued boiling nitrate with the metal, or by gently heating the nitrate; it is a yellow powder. See *Jour. de Pharm.*, July, 1845, and *Chem. Gaz.* iii. 347.

3. *Phosphate*, $\text{Hg}_2\text{O}, \text{PO}_5$, obtained from nitrate of mercury and phosphate of soda, is a white, crystalline powder, insoluble in phosphoric acid, and decomposed by heat. The pyrophosphate is a white powder.

4. *Chlorate* and *perchlorate* are crystallizable; the former forms two modifications and a yellow basic salt; it explodes with combustibles under the hammer. *Bromate* crystallizes from

a solution in excess of bromic acid, and forms a basic salt. The *iodate* is insoluble.

5. A *carbonate* is obtained by dropping the nitrate into a solution of bicarbonate of potassa, and allowing it to remain in the liquid for a time and drying over oil of vitriol in vacuo.

B. *Salts of red oxide, HgO.* 1. *Sulphate.* The neutral is formed by heating 5 pts. oil of vitriol with 4 pts. mercury until the whole forms a dry, saline mass, which bears the heat of beginning redness without decomposition. Water decomposes it into a basic insoluble, and a neutral soluble salt, with free sulphuric acid the salt may be crystallized. The insoluble residue is a lemon-yellow powder, formerly called *Turpeth mineral*, soluble in 2000 cold and 600 boiling water. A basic sulphate with amide, $3 \text{ HgO}, \text{SO}_3 + \text{HgNH}_2$, formed by digesting the neutral salt with ammonia, is a white powder, soluble in nitric and muriatic acids. The sulphate with sulphuret, $\text{HgO}, \text{SO}_3 + 2 \text{ HgS}$, is formed like, and resembles the sulphochloride. The phosphuret and basic sulphate, $4 (\text{HgO}, \text{SO}_3) + 2 \text{ HgO} + \text{Hg}_3\text{P} + 4 \text{ HO}$, is obtained by passing phosphuretted hydrogen in a dilute solution of the sulphate in sulphuric acid, as a white powder, soluble in aqua regia. Double sulphate of ammonia and mercury, $\text{NH}_4\text{O}, \text{SO}_3 + \text{HgO}, \text{SO}_3$, is obtained direct, and is soluble in ammonia. Sulphate with iodide, $\text{HgO}, \text{SO}_3 + \text{HgI}$, is obtained by dissolving iodide of mercury in strong sulphuric acid, and is decomposable by water.

Dithionate is obtained neutral only in solution, but a yellowish basic salt is obtained by treating hyposulphuric acid with more oxide than it can dissolve; its form. is $2 (\text{HgO } \text{S}_2\text{O}_5) + 3 \text{ HgO}$. Double salts of dithionous acid are obtained by dissolving the acid in a soluble dithionite and allowing to crystallize out, or precipitating it by alcohol. The salt of potassa $3 (\text{HgO}, \text{S}_2\text{O}_2) + 5 (\text{KO}, \text{S}_2\text{O}_2)$ is crystallizable and not very soluble; the soda salt is not crystallizable. The ammonia salt, $\text{HgS}_2\text{O}_2 + 4 (\text{NH}_4\text{O}, \text{S}_2\text{O}_2) + 2 \text{ HO}$, is crystallizable and easily decomposed.

2. *Nitrate.* The neutral salt is known in solution only, from which a basic salt separates in crystals with the form. $\text{HgO}, \text{NO}_5 + \text{HgO} + 2 \text{ HO}$. By treating the crystals with lukewarm water, a yellow basic powder remains, $\text{HgO}, \text{NO}_5 + 2 \text{ HgO} + \text{HO}$. When the last is boiled with water, a reddish brown salt is formed, $\text{HgO}, \text{NO}_5 + 5 \text{ HgO}$.

When a dilute nitric solution is precipitated with dilute ammonia, the white precipitate has the form. $\text{HgO}, \text{NO}_5 + 2 \text{ HgO} + \text{NH}_3$, which may be boiled with potassa without setting free ammonia or oxide of mercury. If it be boiled with water, with or without potassa, it becomes heavier, granular, and grayish white, with the form. $(\text{HgO}, \text{NO}_5 + \text{Hg } \text{NH}_2) + 2 \text{ HgO}$, and the same salt is obtained by precipitating nitrate with ammonia and boiling the liquid. Kane obtained a yellowish white precipitate by adding strong ammonia to a strong solution of ammonia, and supposes the compound to be $(\text{HgNO}_5 + \text{HgNH}_2) + 4 \text{ HgO}$. By boiling the first white precipitate with ammonia and nitrate of ammonia, the hot filtrate

gives a yellow deposit, $\text{HgO}, \text{NO}_5 + \text{HgO} + \text{NH}_3$, (*Mitscherlich*), or $\text{NH}_4\text{O}, \text{NO}_5 + (\text{HgO}, \text{NO}_5 + \text{HgNH}_2) + 2 \text{ HgO}$. (*Kane*.) The second grayish white powder, boiled with nitrate of ammonia, yields crystals with the form. $2 (\text{NH}_4\text{O}, \text{NO}_5) + (\text{HgO}, \text{NO}_5 + \text{HgNH}_2) + 2 \text{ HgO}$. (*Kane*.) A solution of the yellow deposit gives a white powder, when ammonia is added to the solution; of the form. $\text{NH}_3, \text{NO}_5 + 3 \text{ HgO}$; and if this powder be dissolved in ammonia in excess, with nitrate of ammonia, yellow crystals separate of the form. $\text{NH}_3, \text{NO}_5 + 2 \text{ HgO}$. (*Mitscherlich*.) A certain excess of ammonia poured into nitrate of mercury throws down a white powder, $\text{NH}_3, \text{NO}_5 + 4 \text{ HgO}$. *Soubeiran*.

Sulphuret and nitrate is precipitated from nitrate by sulphuretted hydrogen, white, $\text{HgO}, \text{NO}_5 + 2 \text{ HgS}$. *Phosphuret and nitrate* is thrown down from nitrate by phosphuretted hydrogen, of a yellow color when anhydrous, white when hydrated; form. $3 (\text{HgO}, \text{NO}_5 + \text{HgO}) + \text{Hg}_3\text{P}$. *Nitrate and iodide* is obtained by half precipitating nitrate of mercury by iodide of potassium, and evaporating the filtrate, or by dissolving mercury in nitric acid to saturation, and dissolving an excess of iodide in the boiling solution until it assumes a color, or an excess of iodide in it. White pearly scales and needles, decomposed by water into nitrate, which dissolves, and iodide which remains; form. $2 \text{ HgI} + \text{HgO}, \text{NO}_5$, or $2 \text{ HgO}, \text{NO}_5$. A double salt is said to be formed with cyanide by mixing nitrate of mercury with cyanide of potassium; form. $\text{HgCy} + \text{HgO}, \text{NO}_5 + 2 \text{ HO}$.

Phosphate of mercury is white and insoluble in water, soluble in phosphoric acid and ammoniacal salts. *Borate* is formed by rubbing together equal equivs. of oxide of mercury and boracic acid, and heating to fusion. By digesting freshly precipitated oxide of mercury with borate of ammonia and evaporating to dryness, a white mass is formed, probably borate and amide of mercury. *Carbonate* is a pale red, insoluble powder, apparently $4 \text{ HgO}, \text{CO}_2$.

5. *Perchlorate and chlorate*, made direct, are crystallizable and deliquescent. A basic chlorate is obtained by dissolving oxide in the acid to saturation, from which solution it crystallizes, as $\text{HgO}, \text{ClO}_5 + \text{HgO} + \text{HO}$. Brooks has described several salts of the two oxides of mercury. Thus his nitrate of black and red oxide has the form. $2 \text{ Hg}_2\text{O}, \text{NO}_5 + 4 \text{ HgO}, \text{NO}_5$. *Chem. Gaz.* iv. 35.

Bromate, formed direct, crystallizes from a hot solution, as $\text{HgO}, \text{BrO}_5 + 2 \text{ HO}$; and by precipitating this solution by excess of ammonia, a yellow basic amide salt is formed; $(\text{HgOBrO}_5 + \text{HgNH}_2) + 2 \text{ HgO}$. *Rammelsb.*

Iodate, formed direct, is a white insoluble powder.

C. On reviewing the compounds of mercury, it is evident that they are of an anomalous character, although some of the analytical results are doubtless erroneous. Millon has endeavored to obviate the difficulty of arranging them with other bodies by assuming the existence of a base in the ammoniacal compounds, as shown in the following table:—

Hydrated base.....	3 HgO + HgNH ₂ + HO + 2 HO.
Base dehydrated over sulphuric acid.....	3 HgO + HgNH ₂ + HO.
Anhydrous base at 266°.....	3 HgO + HgNH ₂ .
Carbonate.....	CO ₂ + 3 HgO, HgNH ₂ + HO.
Carbonate at 275°.....	CO ₂ + 3 HgO, HgNH ₂ .
Oxalate.....	C ₂ O ₃ + 3 HgO, HgNH ₂ .
Sulphate.....	SO ₃ + 3 HgO, HgNH ₂ .
Nitrate of Soubeiran.....	NO ₅ + 3 HgO, HgNH ₂ , HO.
Bromate obtained by Rammelsberg.....	BrO ₅ , 3 HgO, HgNH ₂ .
Chloride obtained by washing the white precipitate with water.....	2 HgO, HgCl, HgNH ₂ .
Iodide obtained by Rammelsberg by boiling ammonia repeatedly with bichloride of mercury....	2 HgO, HgI, HgNH ₂ .

So one of Mitscherlich's salts, (HgO, NO₅ + HgO + NH₃), if doubled, may be (NH₄O, NO₅) + (3 HgO, HgNH₂, NO₅). But instead of regarding HgNH₂ as amide of mercury, it may also be viewed as an ammonia with Hg replacing H. On this theory, chloramide of mercury is analogous to the chloride of ammonium, NH₄, Cl, and may be written NH₂Hg₂, Cl, or NH₂Hg₂ Cl. Since on this view HgO might replace HO, the anomalies of many basic salts disappear.

MESITIN SPAR. *Min.* Is intermediate between BITTER SPAR and SPARRY IRON, and its form. is MgO, CO₂ + FeO, CO₂.

MESITULE. See ACETONE.

MESOLE. *Min.* Cryst. Trimetric. H. = 3.5. G. = 2.35—2.4. In other characters and behavior resembling mesotype. Form. probably 3 NaO (CaO) 2 SiO₃ + 3 (Al₂O₃, SiO₃) + 8 HO. See BREVICITE and MESOTYPE.

MESOLIN. See CHABASITE.

MESOTYPE. *Min.* Syn. Scolezite, Natrolite, Mesolite. Cryst. Right rhombic, also fibrous and acicular. H. = 4.5—5.5. G. = 2.14—2.27. White, yellowish, or reddish; vitreous; transparent, translucent; brittle with uneven fracture. Behavior like the zeolites, (see APOPHYLLITE), scolezite swelling up in twisting forms by heat, and some showing the presence of iron in the fluxes. Soluble in muriatic acid before ignition, the silica gelatinizing. The following are the varieties:

1. *Lime mesotype.* Syn. Scolezite, Needlestone. H. = 5—5.5. G. = 2.2. Partially soluble in oxalic acid. Form. CaO, SiO₃ + Al₂O₃, SiO₃ + 3 HO.

2. *Lime and soda mesotype.* Syn. Mesolite. Partially soluble in oxalic acid. Form. CaO (NaO), SiO₃ + Al₂O₃, SiO₃ + 3 HO of some; others are (NaO, SiO₃ + Al₂O₃, SiO₃ + 2 HO) + 2 (CaO, SiO₃ + Al₂O₃, SiO₃ + 3 HO), or 1 equiv. natrolite + 2 equivs. scolezite.

3. *Soda mesotype.* Syn. Fibrous or prismatic Zeolite, Crocalite, Edelite, Hoganite, Lehuntite, Radiolite. H. = 4.5—5.5. G. = 2.14—2.23. Wholly soluble in oxalic acid. Form. NaO, SiO₃ + Al₂O₃, SiO₃ + 2 HO. It therefore differs from scolezite in containing soda and 2 HO, instead of lime and 3 HO.

The three varieties are found chiefly in Trap rocks. See MESOLE, POONAHILITE, BREVICITE.

MESOXALIC ACID. See URIC ACID.

MESYTELENE. See ACETONE.

METEORIC IRON.

METEORIC STONES. } See AEROLITES.

METACETONE. Formula C₆H₅O. (*Fremy.*) When 1 part of sugar and 3 parts of finely

powdered quick-lime are distilled together, as soon as the temperature reaches 285°, inflammable gas is disengaged, and a mixture of acetone and metacetone remains. The latter is separable by the addition of water, and can be purified by redistillation. The last portions which pass over are to be preserved. Engleberger has recently obtained a fluid ethereal body analogous to metacetone, along with aldehyde and essential oil of bitter almonds, by the oxidation of casein, by the action of peroxide of manganese and sulphuric acid.

Prop. A colorless liquid, miscible with alcohol and ether, but not with water. It boils about 183°. It may be regarded as ACETONE less 1 equiv. of water.

Metacetic acid. C₆H₅O₃ + HO. Obtained by oxidizing metacetone with a mixture of sulphuric acid and bichromate of potassa, and after the disengagement of gas passing over the acetic and metacetic acids by distillation. The two are separable by saturation with carbonate of soda and crystallization. (*Gottlieb.*) Redtenbacher (*Chem. Gaz.* ix. 292) also obtained it from glycerin by slow decomposition, yeast, and access of air, but Gottlieb could not procure it from acetone. Redtenbacher found it among the products of the oxidation of oleic acid by nitric acids. Malaguti, Dumas, and Leblanc also observed it among the products resulting from the decomposition of hydrocyanic ether by potassa. According to these chemists, (*Comptes Rendus*, Nov. 29, 1847), the butyro-acetic acid of Nollner and Nickles, obtained from fermented tartrate of lime, is identical with the metacetic acid, and they propose for it the name of *propionic* acid, in reference to the place which it should occupy in the series of the fatty acids, of which it is the first.

Prop. Very similar in properties to acetic acid, their silver salts having the same solubility. Mixtures of the acetate and metacetone of barytes, copper, zinc, do not crystallize, and moreover the two acids have a great tendency to form double salts in combination with the same base. The acetate of soda, unlike the metacetone, crystallizes readily. (*Gottlieb.*) It also resembles acrylic acid, (C₆H₅O₃ + HO,) from which it only differs by 2 equivs. of water and the fusibility of the silver salt. Very soluble in water, but not in every proportion, and combines easily with ether.

Metacetic ether. Obtained by boiling the metacetone of silver with sulphuric acid and absolute alcohol, and then mixing it with water, when the ether separates as a light liquid of agreeable odor.

Metacetates. The silver salt, $\text{AgO} + \text{C}_6\text{H}_5\text{O}_3$, is in shining white granules, not very sensitive to light, but darkens, and is partially decomposed when heated to 212° . The double salt obtained by decomposing a mixture of acetate and metacetate of soda with nitrate of soda, crystallizes in beautiful lustrous dendritic crystals, and has the formula $\text{C}_4\text{H}_3\text{O}_3, \text{AgO} + \text{C}_6\text{H}_5\text{O}_3, \text{AgO}$.

METALEPSY. See SUBSTITUTION.

METALDEHYDE. See ACETULE.

METAMARGARIC ACID. See MARGARIC ACID.

METAMECONIC ACID. See MECONIN.

METHIONIC ACID. See ETHYL.

METAOLEIC ACID. See OLEIC ACID.

METAPHOSPHORIC ACID. See PHOSPHORUS.

METHYL. *Chem.* Two liquids condensed by the dry distillation of wood, tar, and an aqueous liquid abounding in vinegar, called crude pyroligneous acid. This crude liquid is a solution in water of acetic acid and acetic compounds, wood-spirit, aldehyde, and small quantities of various other substances. If from $\frac{1}{6}$ to $\frac{1}{10}$ of the crude acid be distilled, a spirituous liquid is obtained, commonly termed crude wood spirit, from which a body is obtained analogous to alcohol, together with its ether and a series of compounds similar to those of ether. A larger amount of wood spirit is obtained by distilling woody fibre with caustic potassa, but it is usually prepared from crude pyroligneous acid. From the analogy of wood spirit with alcohol and of its ether with common ether, its radical is called methyl, from *μῆν wine*, whence methylic oxide or meth-er, and methylic alcohol or wood-spirit.

1. *Wood-spirit.* Syn. Proligneous spirit, Pyroxylic spirit, Methylic alcohol, Methalcohol, Formalcohol, Hydrated oxide of methyl, Bi-hydrate of methylen. *Prep.* About $\frac{1}{10}$ or more of the crude pyroligneous acid is distilled, the distillate rectified several times over caustic lime, catching only the lighter portions of it, mixed with sulphuric acid, which separates tarry matter and takes the ammonia, and finally rectified several times over caustic lime, until it no longer clouds by mixture with water, does not brown by exposure to air, does not precipitate nitrate of black oxide of mercury black, and tests neutral. By distilling with caustic lime, it may be obtained anhydrous. The distillations are performed in a water-bath. A better method is to saturate exactly the crude liquid of the first distillation with lime, with chloride of calcium, and after standing for a day or two, to distil it in a water-bath, by which lignone, misit, and a little wood-spirit pass over; then to mix the residue with water, and again distil. The first portions passing over are nearly pure hydrated wood-spirit; the latter portions are adulterated with pyroil.

Prop. Form. $\text{C}_2\text{H}_5\text{O}_2$. A thin, colorless, alcoholic fluid of a peculiar odor, reminding of alcohol and acetic ether. Spec. grav. = 0.798 at 68° , 0.7938 at 77° ; boils at 145° to 150° , quietly, if platinum wire or mercury be introduced into it; spec. grav. vapor = 1120 (by calcul. 1107). It takes fire readily in the air, burning with a slightly less luminous flame than common alcohol: inflames when dropped

on platinum sponge, but the latter in its vapor, air being present, converts it into formic acid, similar to the oxidation of alcohol into vinegar; $\text{C}_2\text{H}_4\text{O}_2 + \text{O} = \text{C}_2\text{H}_4\text{O}_4 + 2\text{HO}$; by distillation with chloride of lime solution, it yields chloroform. By mixing with oil of vitriol, sulphuric mether is formed; by distilling 1 pt. wood-spirit with 4 pts. oil of vitriol, mether (methylic ether) passes over; the higher the heat of distillation, the more sulphuric mether and the less mether distils over. By warming it with potassa lime, hydrogen is chiefly evolved, and there remains formiate of potassa. Wood-spirit mixes with water, alcohol, ether, and dissolves resins, fixed and volatile oils. It forms crystalline compounds with baryta, chlorides of calcium, iron, and tin.

2. *Mether.* Methylic ether, oxide of methyl, hydrate of methylen, Holzäther, Formäther. *Prep.* Gently heat 1 pt. wood-spirit with 4 pts. oil of vitriol, and free the distilling gas from carbonic and sulphurous acids by potassa.

Prop. A neutral gas of ethereal odor, not condensable at $+5^\circ$, soluble in water, imparting an ethereal odor and peppery taste; spec. grav. 1617 (by calcul. 1592). Form. $\text{C}_2\text{H}_5\text{O}$, or as oxide of methyl, $\text{C}_2\text{H}_5\text{O}$; as hydrate of methylen, $\text{C}_2\text{H}_4, \text{HO}$. It burns readily in the air like alcohol; heated in potassa-lime, it forms formiate of potassa; a mixture with chlorine, kept from exploding, is first changed to a liquid $\text{C}_2\text{H}_2\text{ClO}$, or rather $\text{C}_4\text{H}_4\text{Cl}_2\text{O}_2$, then by more chlorine into $\text{C}_2\text{HCl}_2\text{O}$, or better $\text{C}_6\text{H}_3\text{Cl}_6\text{O}_3 = \text{C}_2\text{HO}_3 + 2(\text{C}_2\text{HCl}_3)$, and finally by the action of sunlight and more chlorine into $\text{C}_2\text{Cl}_3\text{O}$, or $\text{C}_4\text{Cl}_6\text{O}_2 = \text{CO}_2 + 3\text{CCl}_2$.

The assumed radical methyl, C_2H_3 , forms a series of compounds with sulphur, chlorine, &c., similar to those of ethyl, and the oxide of methyl or mether, a series of neutral and acid ethers with various acids, similar to those of ether. They are also obtained in a similar manner. See ETHYL.

The following are their formulæ and most important properties: *Sulphuret* of methyl, $\text{C}_2\text{H}_3\text{S}$, or MeS , a liquid, disagreeable odor, spec. grav. 0.845, boils at 106° , spec. grav. of vapor, 2115 (by calcul. 2146). *Sulphhydrate* of methyl, or MeS , HS , boils at 70° , forms a colorless, cryst. double sulphuret with oxide of mercury. *Sulphocarbonate* of methyl, MeS , CS_2 , a yellow liquid, spec. grav. 1.159, boils at 400° . *Oxysulphocarbonate*, a liquid of spec. grav. 1.143, boiling at 338° , and forming a double salt with potassa, with the form. $(\text{KO}, \text{CO}_2 + \text{MeO}, \text{CO}_2) + 2(\text{KS}, \text{CS}_2 + \text{MeS}, \text{CS}_2)$. *Bisulphuret*, MeS_2 , a liquid of strong garlic odor, spec. grav. 1.046, boils at 242.6° . *Trisulphuret*, MeS_3 , distilling at 392° . *Chloride*, MeCl , (muriate of methylen) by distilling 1 pt. wood-spirit, 2 pts. dry common salt, and 3 pts. oil of vitriol, a gas condensing at $+5^\circ$. *Bromide*, MeBr , a liquid of spec. grav. 1.6644 at 32° , boiling at 55.4° . *Iodide*, MeI , also a colorless liquid. *Fluoride*, MeF , a gas of agreeable odor. *Cyanide*, a liquid, forming compounds with other cyanides, as the yellow crystals of $(\text{MeCy} + \text{FeCy}) + 2(\text{FeCy} + 2\text{KCy}) + 8\text{HO}$, formed by dissolving sulphate of methyl and potassa in yellow prussiate of potash. *Rhodanide*, or sulphocyanide, $\text{Me}, \text{C}_2\text{NS}_2$, spec. grav. 1.15, boiling at 270° .

Sulphate of methel. Sulphate of oxide of methyl, $C_2H_5O, SO_3 = MeO, SO_3$, obtained by distilling 1 pt. wood-spirit with 8 or 10 pts. oil of vitriol, is a colorless, oily liquid, of garlicky odor, spec. grav. 1.324, boiling at 370.4° , and distilling unchanged. *Bisulphate*, $MeO, SO_3 + HO, SO_3$, sulphomethyllic acid, bisulphate of methylen, a crystallizable body, forming double salts, like sulphovinic acid. *Isomethionlic acid*, corresponding to the isothionlic acid of the ethyl series. *Nitrate*, MeO, NO_3 , *nitrite* and *hypochlorite* have been made. There is a *biborate*, $MeO, 2 BO_3$, and a basic borate, $3 MeO, BO_3$. *Carbonate* has not been obtained, but it forms double salts with potassa and baryta, and unites with chlorocarbonic acid, to $MeO, CO_2 + COCl$, which is changed by solution in ammonia into *urethylan* or carbamide and carbonic methel, $= MeO, CO_2 + NH_2, CO$. *Oxalate*, MeO, C_2O_3 , a colorless crystallizable body, which, when fused in dry ammoniacal gas, until saturated, forms a white crystalline body, which is oxalic methel and oxamide, $MeO, C_2O_3 + NH_2C_2O_2$, or *oxamethylan*. *Formiate*, MeO, C_2HO_3 , is obtained by distilling sulphate of methyl with formiate of potassa, and boils at 98° . *Basic formiate* of methel (formal, *Kane*, formomethylal, *Dumas*) is obtained by adding to 2 pts. wood-spirit and 2 pts. binocide of manganese in a capacious retort, a cooled mixture of 3 pts. oil of vitriol and 3 pts. water, heating in a water-bath until it begins to foam, when the heat is removed and the distillation continues. It is rectified, and the liquid taken that distils over at $100^\circ - 104^\circ$. It is a colorless liquid, boiling at 100° , and is decomposed by potassa into formic acid and wood-spirit. Form. $3 MeO, C_2HO_3$. If to 120 measures formomethylal in 176 measures water, potassa be added portionwise, and the rising stratum of liquid be removed as it forms, the latter is Malaguti's *methylal*, $C_6H_8O_4$.

Other compounds of methel with organic acids, a large number of which have been investigated, are formed similarly to those of the ether series, by the action of the acid itself on wood-spirit, or by catalysis of wood-spirit by oil of vitriol in presence of the acid, or one of its salts. An interesting compound was found by Proctor, existing in *GAULTHERIA procumbens*.

MIARGYRITE. *Min.* Cryst. Oblique rhombic. $H. = 2 - 2.5$. $G. = 5.234$. Iron-black; submetallic, adamantine; opaque, blood-red in thin pieces; very sectile with red streak. Heated in an open tube, it fuses, yields oxide of antimony and sulphurous acid, and on coal leaves silver. Form. AgS, SbS_3 . Occurs at Braunsdorf, Freiberg, Saxony.

MICA. *Min. Ger.* Glimmer. Three species may be included under this head; potassa or bioxial mica, magnesia or unaxial mica, and lithia mica or lepidolite; but late investigations have shown that neither the optical properties nor the prevalence of a particular alkali can be employed to determine the differences. It is however convenient at present to employ these terms.

1. *Common mica.* Potassa mica, biaxial mica. Cryst. Oblique rhombic, cleaving perfectly, and with a brilliant surface parallel to base. $H. = 2 - 2.5$. $G. = 2.8 - 3$. White,

gray, light green, dark olive green, violet, and brown; lustre, pearly, transparent, translucent; easily separable into very thin, flexible, and elastic laminae. It yields a little water, and often traces of fluoric acid; fuses with variable facility to a grayish yellow, blebby glass; soluble in the fluxes, leaving a skeleton of silica in mic. salt. The following substances have been found in several specimens of common mica: $SiO_3, Al_2O_3, Fe_2O_3, Mn_2O_3, CaO, MgO, KO, F, HO$. The formula for some is, $KO, SiO_3 + 4 (Al_2O_3, SiO_3)$, for one from Jefferson Co., N. Y. $3 (RO, SiO_3) + 2 (R_2O_3, SiO_3)$, + KFl, for another mica, $2 (3 RO, SiO_3) + 10 (R_2O_3, SiO_3) + 3 HO$.

2. *Hexagonal mica.* Magnesia mica, uniaxial mica. Cryst. Hexagonal prisms, with the usual micaceous cleavage. $H.$ and $G. =$ as for common mica. Color, dark green, brown, almost black, lustre often splendid; separates like 1. into elastic laminae. Much less fusible than 1., often giving alone, or with fluxes, a dark iron glass. Form. $3 RO, SiO_3 + R_2O_3, SiO_3$, in which $RO = MgO, KO, FeO$ and $R_2O_3 = Al_2O_3, Fe_2O_3$. The form. is the same as that of Garnet and Idocrase.

3. *Lepidolite.* See LITHIA MICA.

The micas occur chiefly in Primary Rocks.

MICACEOUS IRON. See SPECULAR IRON.

MICAPHYLLITE. See ANDALUSITE.

MICARELLE. See PINITE.

MICA SLATE. A variety of gneiss rock, in which mica is an abundant constituent.

MICHALITE. See OPAL.

MICROCOSMIC SALT. The triphosphate of soda and AMMONIA, much used as a flux in testing with the BLOWPIPE.

MICROLITE. See PYROCHLORE.

MIDDLETONITE. *Min.* In small pieces, the size of a pea; hard and brittle, $G. = 1.6$; reddish brown by reflected, deep-red by transmitted light; resinous; not altered at 400° ; burns like a resin on ignited coal; ether, alcohol, and terpentine are colored yellow when boiled with it; soluble in oil of vitriol and boiling nitric acid with decomposition. Form. $C_{20}H_{11}O, \text{ or } C_{20}H_{10} + HO$. It occurs in the coal of Yorkshire and Staffordshire.

MIEMITE. See BITTER SPAR.

MILDEW. *Agric.* Syn. Rust, Blight. A destructive disease incident to plants, and resulting from an extended deposit of minute, mouldy fungi upon the leaves. In grain fields, its prevention is impossible. Salt and lime, however, are sometimes applied to the soil to prevent communication to the grain from the spreading power of the fungus. In garden plots, the application of flour of sulphur upon the leaves is said to check the ravages of the disease without injury to the plant. For a full treatise, see *Farmer's Encyclopædia*.

MILK. A white, opaque, liquid secretion, varying in its nature with that of the food, health, and species of the animal whence obtained. A healthy cow secretes from 1 to 3 gallons per day. The average of several analyses gives, as the composition of cow's milk:—

Water	87.4
Butter	4.0
Sugar of milk (<i>Lactin</i>) and soluble salts. 5.0	
Casein, albumen, and insoluble salts.....	3.6
The saline portion consists of phosphate of	

lime, magnesia, iron, and soda, chloride of potassium, and caustic soda. Iodide of potassium is sometimes present, and, in addition, Marchand has recently found carbonic acid in fresh milk. For analyses of human and other milk, see Simon's *Chemistry of Man and Chem. Gaz.* vi. 192. The BUTTER or fatty portion exists as CREAM, and rises to the surface when the milk is left to repose. The spec. grav. decreases as the content of cream augments, and ranges from 1.027 to 1.042. Fresh milk is always alkaline, and when this reaction is neutralized by the lactic acid, formed by exposure or agitation from the sugar, the milk coagulates, the CASEIN is rendered insoluble and precipitates with the butter, and leaves the other components in solution as *whey*. This coagulation is not produced in fresh milk by boiling alone, but the addition of acid causes it. Rennet, by the catalytic influence of its chymosin constituent, gives the same reaction, the product being a mixture of casein and fatty matter, and known as *cheese*. The coagulum produced by boiling sour milk is known as *curd*. Coagulation in either way is, however, prevented by the presence of alkaline salts in excess, and hence a slight addition of bicarb. soda, to milk in summer, prevents souring without injury to the milk. In winter, when the low temperature of the atmosphere prevents vinous fermentation, the slow decay of the casein causes putridity, and hence the bitter taste of the butter made in the winter from milk of this kind. To preserve the milk, putrefaction must be prevented, and to this end, Playfair recommends the acetous fermentation in the milk. For this purpose it is placed, *perfectly fresh*, in a suitable vessel and surrounded with hot water at 100° to 110°. The heat may be retained by a cloth cover, and as the water cools, it must be replaced by fresh quantities of the above temperature. In a few hours the milk sours, and a portion of it, when added to fresh milk, kept in a room warmed to 60°, imparts acid, by which the sugar of milk is changed into grape sugar. This latter is then acted upon by the curd and becomes alcohol, which then changes, by oxidation, into acetic acid, and thus renders the whole mass of milk sour, coagulates the casein and protects it from immediate putrefaction. The milk thus treated will last for many days, and give risings of cream for a considerable time; the butter, too, made from it, is sweet and free from bitter taste.

Milk may be rendered portable by mixing it in a natural state with pure white sugar, (4 oz. to the gallon,) agitating thoroughly and evaporating, by steam, in shallow pans, or in a drying chamber at 122°. The layers of milk should not exceed one-tenth of an inch in depth. As it approaches solidity, it is removed from the pans and pressed into cakes. These cakes are soluble in warm water, and retain their freshness and sweetness for a long time.

MILOSCHIN. *Min.* A green clay from Servia, has the form. $3\text{R}_2\text{O}_3, 2\text{SiO}_3 + 9\text{HO}$, in which $\text{R}_2\text{O}_3 = 45, \text{Al}_2\text{O}_3 + 3.6\text{Cr}_2\text{O}_3$.

MIMPTESITE. *Min.* Syn. Green lead ore. Cryst. Hexagonal, prismatic. $H. = 2.75 - 3.5$. $G. = 6.41$. Yellow, passing into brown; resinous; subtransparent, translucent; sectile.

Fuses with more difficulty than pyromorphite, crystallizing on cooling, gives arsenical odor, and may be reduced to lead. Form. see under ARSENIOPHOSPHATES. Cornwall and Johamgeorgenstadt. See HEDYPHAN, PYROMORPHITE.

MINDERERUS, SPIRITS OF. The dilute aqueous solution of acetate of ammonia, formed by neutralizing distilled vinegar with carbonate of ammonia.

MINERAL ALKALI. See SODA.

MINERAL CAOUTCHOUC. See ELASTIC BITUMEN.

MINERAL CHARCOAL is sometimes found in anthracite coal, in layers of one or more inches in thickness.

MINERAL GREEN. See CARBONATE OF COPPER.

MINERAL OIL. See PETROLEUM.

MINERAL PITCH. See ASPHALT.

MINIUM. *Min.* Red crystalline scales, or powder; $G. = 4.6$. Easily reduced to lead, darkens by heat, but reddens on cooling. Form. $2\text{PbO}, \text{PbO}_2$, which is Red LEAD. Austin Mines, Wythe Co., Virginia; Mine à la Motte, Madison Co., Missouri, with white lead.

MISPICKEL. Syn. Marcasite, Danaite. *Ger.* Arsenikkies. Cryst. Right rhombic, prismatic, vertical, and horizontal prisms, cleaving parallel to vertical prism. Also columnar, granular. $H. = 5.5 - 6$. $G. = 6.127$. Silver-white; metallic; brittle, with grayish black streak. Gives in a tube a red and then brown sublimate of sulphuret of arsenic, then metallic arsenic; after expelling arsenic on coal, a black magnetic globule remains, in which borax often proves the presence of cobalt, soluble in nitric and nitromuriatic acids, leaving sulphur and arsenious acid. Form. $\text{FeS}_2 + \text{FeAs}$. In that from Skutterud, Norway, and Franconia, N. Hampshire, part of the iron is replaced by cobalt, up to 9 pr. ct.

MOCHA STONE. See QUARTZ.

MOHRINGA, OIL OF. *Chem.* Syn. Oil of Ben. Walter's investigations gave the following results:—

The oil of ben does not yield, on saponification, any volatile fat acid, but four fixed fat acids, viz., stearic, margaric, and two new acids, which the author calls *benic* and *moringic* acids.

The benic acid occurs in very small quantity in the oil of ben; it consists of $\text{C}_{30}\text{H}_{30}\text{O}_4$, and consequently belongs to the homologous series, RO_4 , being situated between myristic and ethalic acids. It crystallizes from its alcoholic solution in very voluminous tufts, and fuses at 126°–127°. Benic ether is very soluble in alcohol, and is deposited from the solution as a crystalline mass, but not in distinct crystals; it melts at a very low temperature, even by the heat of the hand, and contains $\text{C}_{34}\text{H}_{34}\text{O}_4$; it is isomeric, therefore, with margaric acid.

The other new acid, obtained by the saponification of the oil of ben, has been called *moringic* acid, from the name of the plant (*Moringa aptera*) which yields the oil. It is liquid, colorless or somewhat yellowish, and contains $\text{C}_{30}\text{H}_{28}\text{O}_4$, that is to say, 2 equivs. of hydrogen less than benic acid. From its composition it appears to be homologous to oleic acid. It would be interesting to ascertain whether, like

the last, it would be decomposed under the influence of fusing potash into two acids of another homologous series. Its density is 0.908, its taste insipid and irritating, its smell faint; it reddens litmus paper, and is very soluble in ordinary spirit, even in the cold; it solidifies at 32° Fahr.; it is decomposed by sulphuric acid on the application of heat.

M. Walter has verified the composition of this new acid by an analysis of the ethers it yields with alcohol and wood-spirit. (*Comptes Rendus*, xxii. p. 1143.)

MOHSITE. Allied to CRICHTONITE.

MOLASSES See SUGAR.

MOLECULES. The elementary or compound atoms into which bodies are divisible. When brought in contact by the force of COHESION, they produce the solid, liquid, and gaseous states of bodies accordingly as their contact is more or less intimate. A complex organic molecule is defined by Graham as "an association of two or more binary compounds, comparatively simple in constitution, often insoluble substances, and possessed of considerable stability." See AFFINITY.

MOLYBDENITE. *Min.* Molybdänglanz. Cryst. Hexagonal, prismatic; usually in lamina. $H. = 1-1.5$. $G. = 4.57-4.74$. Dark lead-gray; metallic; opaque; very sectile, soiling the fingers. Distinguishable from graphite by the olive-green streak it leaves on porcelain, and by its chemical reactions. Held in the pincette it colors flame-green; gives off sulphurous acid on coal, and a white coating; a bead of borax with saltpetre is colored brown in the inner flame. Decomposed by boiling nitric acid, leaving white molybdic acid; wholly soluble in aqua regia with a greenish, in oil of vitriol with a blue color; by fusion with potassa it gives in water a brown solution. Form. MoS_2 . It occurs chiefly in gneiss in many European and American localities. The finest locality is the island of Virgin Gauda, in a copper mine, where large masses have been found.

MOLYBDENUM. *Chem.* A white metal, with the lustre of unpolished silver, found by Scheele in a native sulphuret resembling graphite, and hence its name from the Greek, for that substance. It may also be obtained from MOLYBDIC LEAD.

Prop. Sym. Mo. Eq. 48, (596.1, O. = 100 Berz.) Spec. grav. 8.615; spec. heat .0659 (*Dulong & Petit*), or .07218 (*Regnault*). Obtained by reducing any of the oxides in a brasqued crucible or by hydrogen. Fuses with difficulty, oxidizes superficially by exposure to air, and when heated to redness turns brown, then blue, and is ultimately transformed into molybdic acid. Hydrochloric, phosphoric, and hydrofluoric acids are without action.

Oxide. Form. MoO . Prepared by dissolving a molybdate in excess HCl acid, and digesting the liquid with zinc. Is deep brown and soluble in acids. Heating in a close vessel dehydrates it and destroys its solubility in acids; and though also insoluble in the alkalies, is taken up by carbonate of ammonia. Heated in contact with the air, it oxidizes. The salts of the oxide are dark gray or black, in solution black or purple colored; sulphuretted hydrogen gives

a brownish black precipitate; sulphuret of ammonium a black, soluble in an excess of the precipitant; caustic and carbonated alkalies black hydrated oxide.

Binoxide. Form. MoO_2 . Precipitated by ammonia, as hydrate, from an aqueous solution of chloride, prepared by passing dry chlorine over the metal. Is very similar in appearance to peroxide of iron; dissolves slightly in water. When dehydrated, it browns and loses solubility in acids. The hydrate reddens litmus, but does not act as an acid. It dissolves in the alkaline and in some earthy carbonates, but is insoluble in caustic alkalies. The salts of this oxide are brown. The precipitate formed by hydrosulphuret of ammonia in its solution is soluble on excess of the reagent. Treated with nitric acid it becomes—

Molybdic acid. Form. MoO_3 . Prepared by roasting the native sulphuret at a low red heat. The impure yellow acid thus obtained is whitened by solution in caustic ammonia, filtration of the liquid, evaporation of the filtrate, refiltration, and precipitation by an acid. Spec. grav. 3.5. Is fusible, and becomes crystalline and yellow on cooling. Sublimes from an open vessel into brilliant silky needles. Is soluble in 570 pts. cold, and more so in hot water. Previous to calcination is soluble in acids forming compounds, in which it acts as the base. It combines also with bases forming colorless, crystallizable salts, of which those with the metallic bases are insoluble. Metals, acids, or salts having a strong affinity for oxygen reduce this acid to an intermediate blue oxide. The bimolybdate of soda has the composition $NaO, 2 (MoO_3), 7 HO$.

Molybdates of the Oxide of Molybdenum. Molybdic acid combines with the binoxide in different proportions, forming intermediary oxides of beautiful blue or green tints.

The blue compound, termed by some chemists *Molybdous acid*, $MoO_2, 4 (MoO_3)$, is obtained by passing hydrogen over molybdic acid heated to low redness. Is soluble in water and precipitable by salammoniac. Air, chlorine, and nitric acid transform it into molybdic acid.

The green compound has the composition $MoO_2, 2 (MoO_3)$.

Sulphurets. There are three compounds with sulphur, viz., the bisulphuret, MoS_2 , the sulphide, MoS_3 , and the persulphide, MoS_4 . The first is found native, and resembles plumbago, see MOLYBDENITE. The second is prepared by decomposing a concentrated solution of a molybdenite with sulphuretted hydrogen, and precipitating the liquor with an excess of acid. A deep brown deposit, becoming black by drying, is formed. By sublimation, sulphur is eliminated, and the residue is bisulphuret. Dissolves slightly in caustic alkalies, and readily in the monosulphuret of potassium. The third or persulphide is deep red when moist, assuming a gray, metallic lustre on drying, and yielding a cinnamon powder. Both these last sulphurets unite with alkaline and other basic sulphurets to sulphosalts, those of the former being sulphomolybdates, of the latter persulphomolybdates.

Chloride of M. The proto-compound formed by dissolving molybdous oxide in HCl acid. It forms double salts with the chlorides of potas-

sium, sodium, and ammonium. The bi-salt, MoCl_2 , is prepared by heating molybdenum in dry chlorine gas. The resultant gas condenses into iodine-like crystals. Is fusible and soluble in water, producing ebullition. The perchloride, MoCl_3 , produced by dissolving molybdic acid in HCl acid, is in the form of a dry, white mass, soluble in water.

There are two other compounds with chlorine,—the basic chloride, and the bi-acid chloride (*Chloromolybdic acid*), $\text{MoCl}_3 \cdot 2 \text{MoO}_3$.

Sulphate. $\text{MoO}_3 \cdot \text{SO}_3$. Prepared by dissolving the hydrated protoxide in sulphuric acid.

MOLYBDIC LEAD. *Min. Ger.* Gelbbleierz. Cryst. Quadratic, composed of several 8-hedra; also granular. $\text{H.} = 2.75 - 3$. $\text{G.} = 5.7 - 6.76$. Various shades of ochre-yellow, red, gray, green; resinous; translucent; brittle with white streak. Decrepitates by heat; fuses on coal and gives lead; behaves to fluxes and acids like molybdic ochre modified by the presence of lead. Form. PbO , MoO_3 . Occurs at Bleiberg, Retzbanya, Moldawa; Southampton, Conn.; and Perkiomen, Philadelphia.

MOLYBDIC OCHRE. *Min.* A yellow, earthy incrustation. It fuses on coal, fumes, and coats it; in borax, in the outer flame, it gives a colorless, in the inner, a brown glass; in mic. salt, in the outer flame, a bead, green while hot, colorless when cold; in the inner, blue or black while hot, green when cold; yields a gray, metallic powder by reduction with soda: soluble in muriatic acid and in potassa. Formula probably MoO_3 .

MONAZITE. *Min.* Mengite, Edwardite. Eremite. Cryst. Oblique rhombic. $\text{H.} = 5$. $\text{G.} = 4.8 - 5$. Yellowish or reddish brown, brownish red; vitreous; subtransparent, subtranslucent; rather brittle. Infusible; moistened with oil of vitriol, it colors flame greenish blue; soluble in the fluxes to a yellowish red glass, which becomes colorless on cooling; with soda it yields tin in the mortar, and shows manganese on platinum; soluble in muriatic and dilute sulphuric acids. It is probably 3RO , PO_5 , (*Berz.*); $\text{RO} =$ oxides of cerium and lanthanum and thorina. Hermann's gives no thorina, but Berzelius, after examining Kersten's thorina, says that it certainly contained neither cerium nor lanthanum, and behaved exactly like thorina. From the Ural; Norwich and Chester, Conn.; Yorktown, Westchester Co., N. Y.

MONESIA. The true origin of this new drug is still unknown. It must be derived from some rather large tree, perhaps from a *Chrysophyllum* (*Sapotee*). Guibourt has received samples of bark with the name *Buranhem* attached to them, which he considers to be monesia. Some travellers suppose the bark to owe its origin to *Rhizophora gymnorhiza*, Linn. (*Bugiera gymnorhiza*, Lam.), but this is most probably incorrect. It resembles the barks of *Acacia cochleocarpa*, Mart. (*Cort. Brasiliensis*, Pharm. Hamb.), and *Acacia virginialis* (*Cort. barbatimao s. Brasiliensis*, Pharm. Lisb.), but is certainly distinct. Nothing can be deduced from the name, for the bark decidedly does not belong to a *Monetia* or *Manetia*, *Rubiaceae*.

The extract of monesia forms blackish brown, very brittle tablets, from 20 to 25 millimetres in thickness. On the surface of fracture they

do not in the least resemble catechu and kino. In water it is entirely soluble, and has at first a sweetish, subsequently astringent and irritating taste, resembling in many respects that of *Succ. liquiritiae*. It occurs in commerce under the name of monesia, in bottles, which are filled with the extract in solid fragments. Whether the extract is first prepared in Paris from the bark, or is imported direct from South America, is not known.

The chemical analysis of the bark afforded the following results:—

Essential oil (?), crystallized stearin, chlorophyll, and wax	1.2
Glycyrrhizin	1.4
Monesin (an acrid extractive substance, resembling saponin)	74.7
Tannin	7.5
Red coloring matter (similar to kino red and catechu red)	9.2
Traces of gum, malic acid, and malate of lime	1.3
Phosphate of lime and magnesia, sulphate of potash, chloride of potassium, malate of potash, oxide of iron, oxide of manganese, and silica	3.0
Pectin, fibrin, and loss	71.7

Monesin. Obtained by extracting the bark with hot alcohol of 0.906 spec. grav., adding to the tincture an excess of slaked pulverized lime, and shaking till it is rendered colorless. The magma, consisting of lime in combination with tannin, red coloring matter, malic acid, and glycyrrhizin, &c., is separated; the clear liquid distilled and dried, the residue again dissolved in water, treated with some animal charcoal, filtered and dried in the water-bath. An amorphous, slightly yellowish, gummy, transparent residue is obtained, which may be reduced to a white powder easily soluble in water and in alcohol, but scarcely at all in ether. The aqueous solution froths very much. Monesin cannot be obtained in a crystallized state under any circumstances. It is void of smell, at first of a bitter taste, but soon becoming acrid and irritating in the windpipe. It does not saturate acids; it is converted by nitric acid into a yellow, easily pulverizable substance, which is scarcely soluble in water, but very easily in alcohol, is very bitter, and on evaporation of the solution affords crystalline laminae. It behaves towards hydrochloric acid and potash like saponin, polygalic acid, æsculic acid, salsaparin, &c. and evidently belongs to the class of saponoid irritating extractive substances, the knowledge of which is still very imperfect. *Derosne, Henry, & Payen.* (*Journ. de Pharm.* 1841.)

MONOPHAN. See **EPISTILBITE**, p. 595.

MOURADITE. *Min.* Massive, crystalline, reddish, yellow, vitreous. $\text{H.} = 6$. $\text{G.} = 3.267$. Yields water, is infusible, and with borax and mic. salt shows the presence of iron and silica. Form. $4 (3\text{RO}, 2 \text{SiO}_2) + 3 \text{HO}$, $\text{RO} = \text{MgO}$, FeO . From Bergen, Norway.

MOONSTONE. See **FELDSPAR**.

MONTICELLITE. Colorless **CHRYSLITE**.

MORDANT. See **DYEING** and **CALICO PRINTING**.

MORIN. See **FUSTIC**.

MORINDIN. *Chem.* $\text{C}_{23}\text{H}_{15}\text{O}_{15}$ (*Anderson*).
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The coloring mater, of the sooranj plant (*Morinda citrifolia*) of Bombay, extracted by boiling alcohol. Forms yellow, silky crystals, insoluble in ether, but soluble in boiling dilute spirit and hot water, from which latter it deposits as a gelatinous precipitate. With alkalis, it gives orange-red solutions. By heating, it is changed into beautiful crystals of *morundone*, $C_{28}H_{10}O_{10}$. *Chem. Gaz.* vi. 317.

MOROXITE. See APATITE.

MORPHIA. *Chem. Pharm.* The essential and most abundant of the bases found in OPIUM, of which it forms 5 to 10 pr. ct., according to quality. Formula $C_{35}H_{20}NO_6$. Dolfus gives $C_{34}H_{18}NO_6$ (*Liebig's Annalen*, 1848, p. 212), and Laurent $C_{34}H_{19}NO_6$ as the formula.

Prep. Mohr's plan is to macerate opium in thin slices with water, and to repeat the operation thrice with fresh water. To the warm filtrate boiling milk of lime (containing of lime equal to $\frac{1}{6}$ or $\frac{1}{4}$ the weight of the opium) is added, and the whole heated to ebullition. The mass is then strained through muslin, and the intercepted matter well washed with boiling water and pressed. The liquids, being collected together, are afterwards evaporated to double the weight of the opium, and filtered rapidly to avoid the formation of carb. of lime. The filtrate, while boiling, is then treated with 1oz. salammmonic to every pound of opium. The morphia thus precipitated, nearly colorless, is to be redissolved in HCl acid, boiled with milk of lime, and reprecipitated by muriate of ammonia, (1 part to 16 of opium), which throws it down entirely. The eminent decolorizing power of the lime renders unnecessary the use of bone black.

There are other processes, of which the two most practicable and economical are that of Gregory and the following:—Reduce the opium to thin slices, macerate it in cold water for several days, and during the interval knead it thoroughly once or twice daily. Repeat this treatment with fresh water twice, press the residue, mix together the clear liquids, and evaporate to a syrupy consistence. Add a little very dilute water of ammonia, strain and evaporate again: repeat this treatment so as to separate as much as possible the extractive, which would otherwise be a serious hinderance to the success of the process. The filtrate from this extractive is then to be treated, during constant stirring, with ammonia until it barely smells of it, for if an excess is used, a portion of the morphia is retained in solution. The morphia thus precipitated is then thrown upon a strainer, washed with cold water, and pressed. To separate narcotin and any residual resinous matter, the pressed cake must be digested with alcohol of 20° Baumé, at 85° Fahr. If one treatment with alcohol does not suffice, a second must follow. The purified morphia may then be dissolved in strong boiling alcohol, decolorized by bone black, and allowed to crystallize out; or it may be converted into muriate, and after purification by repeated crystallizations, precipitated by ammonia, to be obtained in larger crystals from resolution in strong alcohol, or to be neutralized by acids for the formation of salts.

The plan of converting the crude morphia at this stage directly into muriate, is recom-

mended as far more economical than the use of alcohol, or the conversion of it into a sulphate, as the former salt crystallizes more readily, abundantly, and with less color. When the muriate is perfectly white, it may be brought to solution, and its morphia precipitated in pure white minute crystals, then to be recrystallized from alcohol, or converted into salts, as may be desired. The amount of mother water is in this way decreased, and consequently also the number of precipitations by ammonia for the collection of residues. This is a very important point, for when morphia is repeatedly precipitated by ammonia from its solutions, and especially from the sulphate, its character is altered, a portion of it becoming almost wholly insoluble in alcohol, and very difficultly soluble in acids. The more there is formed of this insoluble portion, the less the product of the opium. *Morfit.*

Prop. Crystallizes in colorless four-faced prisms, slightly soluble in water, and still less so in ether. Soluble in 40 parts of cold anhydrous and 30 of boiling common alcohol, in the fat and essential oils, and in the caustic alkalies. This property of solution in caustic potassa distinguishes its purity from narcotin; and in that of being also taken up by caustic lime is founded Mohr's process for its preparation. When heated, it loses 2 equivs. of water and becomes opaque, and at 570° is decomposed. Strong nitric acid colors it red, as does also a solution of gold; perchloride of iron imparts a fugitive blue, and iodic acid, brown, iodine being eliminated.

It unites readily with acids, and forms salts which are crystallizable, bitter, generally soluble in water and alcohol, but insoluble in ether. They are precipitated by the carbonated and caustic alkalies, an excess of the latter however redissolving the precipitate.

Muriate. $\overset{+}{M}, HCl + 6 Aq.$ Forms groups of white silky crystals, unalterable on exposure.

Sulphate. $\overset{+}{MSO_3} + 6 Aq.$ Crystallizes in fine colorless feathery prisms, very soluble in water, and unalterable upon exposure at common temperature.

Acetate. Difficultly crystallizable, and loses a part of its acid when its solution is evaporated. The acetate made by the double decomposition of the sulphate of morphia and acetate of lead is much less prone to absorb moisture than that formed by direct union of the base and acid.

Sulpho-cyanate. $\overset{+}{M}, C_2NS_2H + HO.$ Forms small, transparent, shining needles, which melt at 212°. It is made by saturating the alkaloid dissolved in alcohol, with moderately dilute sulphocyanic acid. *C. Dolfus.*

When morphia is treated with an excess of sulphuric acid and the liquid evaporated to incipient decomposition, the brownish mass yields to boiling water, and a white body becoming green after a time. This peculiar substance, first obtained by Arppe, (*Ann. der Chem. und Pharm.*, lv. p. 96), is called by Laurent and Gerhardt (*Journ. de Pharm.* 1848, p. 302) *sulpho-morphide*, equal to neutral sulphate of morphia, minus 2 equivs. of water, thus, $SO_4 (H_2, 2 C_{17}H_{19}NO_3) - 2 OH_2$. It is non-vola-

tile, slightly soluble in water, and insoluble in alcohol and ether.

MORVENITE. See HARMOTOME.

MOSAIC GOLD. Syn. Aurum musivum. The alchemical term for bisulphuret of Tin.

MOSANDRITE. *Min.* Massive and fibrous. H. = 4. G. 2.93 — 2.98. Reddish brown; greasy and resinous; translucent with a red light; grayish brown streak. It yields much water in a tube; becomes brownish yellow by heat, and fuses readily with puffing to a brownish green bead; with soda and borax shows manganese, and with mic. salt silica, and in the inner flame titanic oxide; wholly decomposed by muriatic acid. It is a silicate and titanate of cerium and lanthanum, with manganese, lime, magnesia, potassa, and water. Occurs at Lammanskaret, Sweden.

MOTHER WATER. The chemico-technical name given to the residual solution, which has been weakened by the crystallization and separation of the most of its dissolved substance.

MOULD. *Chem. Agric.* Syn. Garden Mould, Humus, Vegetable mould. A natural compost of garden earth and decayed vegetable matter, containing as the result of organic decomposition, humus coal, humin, humic, geic, and ulmic acids, mineral and other substances. This decay or eremacausis of organic matter in soils gradually transforms them into turf, and is retarded or prevented by the use of antiseptics. (See DECAY of Wood.) It is a dark brown or black powder, and invariably contains carbonate of ammonia (*Liebig*), besides the salts and alkalies left behind by the putrefaction of other plants. Of 100 parts of the ashes of the mould from an hollow oak, 24 were soluble salts with alkaline bases, 10.5 earthy phosphates, 10 earthy carbonates and 32 parts silica. The aqueous extract gave 66 pr. ct. soluble salts (*Saussure*). Cold water takes up only $\frac{1}{10,000}$ th of its own weight of vegetable, and gives a clear and colorless solution, but boiling water extracts several substances and takes a yellowish brown color, which it loses by absorption of oxygen from the air, a black flocculent deposit being formed. Its efficiency in promoting the growth of plants is due to the alkaline salts which it contains, as well as to its property of absorbing and fixing the ammonia of the atmosphere.

Humus coal and Humin. Those modifications of humus insoluble in alkalies. The formula for humin is $C_{40}H_{15}O_{15}$.

Humic acid. Isomeric with humin, but loses 3 equivs. of water by heat and becomes $C_{40}H_{12}O_{12}$. Both are brownish black. It exists as one of the products of the action of HCl or SO_3 acid upon SUGAR. Mulder obtained it by treating PROTEIN with HCl acid, and has recently also extracted it from soot.

Very concentrated potassa transforms it into a black insoluble substance, $C_{34}H_{13}O_9$, which, by prolonging the action with aid of heat, becomes $C_{34}H_{10}O_6$. Nitric acid changes it into apocrenic acid.

Chlorohumic acid, resulting from the action of chlorine gas, in the presence of water, upon ulmic as well as humic acid, is a red-brown powder, soluble in alcohol and precipitable from its solution in concentrated sulphuric acid by water. It forms salts with the par-

ticular bases, of which that of baryta has the formula, $C_{32}H_{12}ClO_{16}$, BaO, HO.

Nitro-humic acid. A red powder generated by the action of NO_5 upon humic and ulmic acids. It is solid, amorphous, soluble in water and alcohol, insoluble in ether, and forms red salts with the alkalies. Boiling with potassa, disengages ammonia. Mulder considers this acid only the apocrenate of ammonia = $C_{46}H_{12}O_{24}$, and $NH_3 + 2$ Aq.

Geic acid is also one of the products of humus. The formula of its ammoniacal compound is $C_{40}H_{12}O_{14} + 2NH_3$, HO.

Ulmic acid. Obtained in combination with ulmic acid, as ultmate of ulmin ($C_{40}H_{16}O_{14}$). Like humin, it is also obtained by the action of SO_3 upon sugar. This salt being decomposed by potassa, ulmin ($C_{40}H_{16}O_4$) precipitates. The *ulmic acid* is separated from the potassa by HCl acid, and falls as gelatinous flocculæ, soluble in water, free from acid and salts. The hydrated acid is isomeric with ulmin, but at 383° it loses water and becomes anhydrous, and = $C_{40}H_{14}O_{12}$.

Crenic and Apocrenic acids. These acids also exist, combined with ammonia, in mould, but the latter may be made artificially by the action of NO_5 and potassa upon humic acid. (*Chem. Gaz.* iii. 2.) The free apocrenic acid, hydrated, has the formula, $C_{48}H_{12}O_{24} + 2$ HO, and crenic acid $C_{24}H_{12}O_{16}$. Mulder (*Jour. für Prakt.* xxxii. 321) attributes their formation in soils to the action of the nitric acid, generated by the union of the oxygen of the atmosphere with the ammonia combined with the humic acid, and on this account no true nitrification takes place.

MOUNTAIN LEATHER. See ASBESTUS.

MOUNTAIN GREEN. See MALACHITE.

MOUNTAIN SOAP. Allied to BOLE.

MOUNTAIN TALLOW. See HATCHETIN.

MOUNTAIN WOOD. *Min.* Bergholz, from Sterzing, has a different composition from asbestos. It yields water in a tube, and is readily decomposed by muriatic acid. Form. $Fe_2O_3, 3SiO_3 + 2(MgO, SiO_3) + MgO, 5$ HO.

MUCIC ACID. A product of the oxidation of SUGAR of milk.

MUCILAGE. See GUM.

MUCUS. The viscid, stringy, nitrogenous fluid, secreted by the mucous surfaces of the body. It is generally grayish white and turbid, but sometimes clear and colorless, and of sufficient consistence to separate in tough flocculi.

Prop. Normal mucus when fresh is heavier than water, and the retention of air bubbles is the cause of its floating upon that liquid, and being insoluble therein. Dilute acetic, oxalic, and tartaric acids destroy the granular appearance of the corpuscles, a change not produced by dilute mineral acids in the capsules. Its liquid portion gives an alkaline reaction, and on the addition of water coagulates and drops a fine granular precipitate.

Mucus consists of:—Mucus corpuscles, epithelium cells, mucin, traces of extractive matters, fat, chlorides of potassium, sodium, alkaline lactates, traces of carbonate of soda, phosphate of lime, and occasionally of albumen.

Mucin. The peculiar animal matter of mucus is, according to Eicholtz, identical with

MUDARIN.

PYIN. When allowed to remain in contact with water, the presence of free alkali enables the solution of the mucin, which is readily precipitated by a slight addition of acid. On evaporating an alkaline solution of mucin over a water-bath, it becomes covered with a film of coagulated mucin, which is difficultly soluble in water. (*Simon.*) The mucin of vegetable juices is written of as mucose under GUMS.

MUDARIN. Obtained by evaporating the alcoholic extract of the bark of the root of the *Calatropis mudarii*. A brown transparent mass, very soluble in water and alcohol, insoluble in ether, ess. of turpentine, and the fat oils. Its aqueous solution forms a jelly at 95°, and finally coagulates.

MUFFLE. A fire-clay arch fitted to ASSAY furnace, and used to protect the crucible or cupel from dirt and ashes.

MULLER'S GLASS. See OPAL.

MULLICITE is VIVIANITE.

MUNDIC. See IRON PYRITES.

MUREXAN. } See URIC ACID.

MUREXIDE. }

MURIACITE. See ANHYDRATE.

MURIATIC ACID. See CHLORINE.

MUSK.

MURICALCITE. See RHOMB SPAR.

MUSCOVY GLASS. See MICA.

MUSSITE. See AUGITE.

MUSCLE. Differs from the fibre of cellular tissue in not yielding gelatine by prolonged boiling in water. Its precipitation from solution in acetic acid by ferrocyanide of potassium, shows it to be a protein compound. Pure muscle is difficultly separable from its concomitants; freed as much as possible from fat and cellular tissue, blood, extractive matter, &c., it becomes colorless. Cold water and alcohol are without effect, but in boiling water it contracts, becomes firm, and finally softens. Dried muscular fibre is readily pulverizable. *Simon.*

Liebig has recently proven the existence of both free lactic and phosphoric acids in the substance of muscle.

MUSHROOMS. Doëpping and Schlossberger, in a recent examination of piths, found that the substances soluble in water contained both mannite and a fermenting sugar. The following are the results of analyses of several mushrooms by the above-named chemist. The ashes contained a large amount of phosphates, and some of them manganese.

	Water.	Dry parts.	Nitrogen, fresh.	Nitrogen, dry.	Ashes of the dry.
<i>Agaricus deliciosus</i>	86.90	13.10	0.61	4.68	6.90
“ <i>arvensis</i>	90.61	9.39	0.68	7.26	10.82
“ <i>glutinosus</i>	93.71	6.29	0.29	4.61	4.80
“ <i>ursula</i>	91.20	8.80	0.37	4.25	9.50
“ <i>cantharellus</i>	90.60	9.40	0.30	3.22	11.20
“ <i>muscarius</i>	90.56	9.44	2.598	6.34	9.00
<i>Boletus aureus</i>	94.25	5.75	0.26	4.70	6.80
<i>Polyporus fomentarius</i>				4.46	3.00
<i>Dedalea quercina</i>				3.19	3.10

MUSHROOM SUGAR. See SUGAR.

MUSK. The inspissated secretion in the follicle of the prepuce of the *Moschus moschiferous* (male musk-deer). The three varieties

are the *Chinese Tonquin*, *Thibetian*, or oriental musk, the *Russian* or *Kabardinian*, and the *Bucharian*. For description, see *Pereira*, ii. 804, and *Chem. Gaz.* i. 686.

Geiger and Reinmann's analysis gave—

1. Peculiar volatile substance..... Quantity undeterminable.
2. Ammonia..... Ditto.
3. Peculiar, fixed, uncrystallizable acid..... Ditto.
4. Stearin and olein..... 1.1
5. Cholesterin (with some olein and resin)..... 4.0
6. Peculiar bitter resin..... 5.0
7. Osmazome (with salammoniac, chlorides of sodium and calcium, and the above acid, partly free, partly combined with the bases)..... 7.5
8. A mouldy-like substance, in part combined with ammonia, by which it is made soluble in water, with small quantities of phosphates of lime and magnesia, sulphate of potash, chlorides of potassium and sodium, carbonate of potash or soda, and trace of iron..... 36.5
9. Sand..... 0.4
10. Water, some volatile odorous matter, the above acid in part combined with ammonia, and loss..... 45.5

100.0

The odorous matter, which is non-volatile, is not peculiar to musk, since many other substances exhale a similar smell. Robiquet attributes it to ammonia, which being disengaged carries with it substances not otherwise volatile, and of scent strong enough to mask the ammoniacal odor.

Adulterations. Owing to its high price, musk is generally adulterated with dried blood, and

to increase the weight of the pods, pieces of lead are frequently introduced. The Tonquin pods should be dry and covered with a slightly brown, hairy mass. A whitish down indicates an inferior article of Bengal. A good test of the odorous power of musk is to perforate the pods with a wire which has been dipped in the juice of garlic. The dissipation of the smell proves the purity of the musk. Neligan pro-

poses to distinguish the true sacs from the false by the microscopic characters of the hairs which grow on the preputial sac of the musk animal. (See *Chem. Gaz.* iv. 80.)

Artificial musk. Prepared by gradually adding 1 pt. rectified oil of amber to 3 pts. fuming nitric acid, and washing the resin obtained with water. Is soluble in alcohol, ether, and the essential oils. The odor, in large quantities, resembles that of amber resin, but in smaller quantities that of musk. Elsner gives $C_{15}H_8NO_7 + PbO$ as the composition of its lead compound. According to this chemist, it is succinic-eupione resin.

MUST. A term properly belonging to the unfermented saccharine juice of the grape, but also applied to the worts and fermentable juices generally.

MUSTARD SEED. The seeds of the *Sinapis nigra* contain myronate of potassa, myrosin, fixed oil, fatty, gummy, and coloring matters, a peculiar green matter, sugar, sinapisin, free acid, and salts.

Sinapisin. An indifferent principle extracted by ether from the evaporated absolute alcoholic tincture of black mustard seeds. It forms micaceous crystals, and in behavior is analogous to the non-saponifiable crystalline fatty matters. It is volatile, soluble in alcohol, ether, and the oils, but insoluble in acids and alkalies (*Simon*), and not convertible into essential oil by myrosin. *Baudrimont*.

Myrosin. A principle analogous in physical properties to the *emulsin* and *synaptose* of almonds. It is separable from the white mustard seed by maceration in cold water, evaporating the filtered liquid to a syrupy consistence, at a temperature not exceeding 104°. The residue, treated with alcohol, drops the myrosin, which must be separated, dissolved in water, and evaporated gently, and at a mild heat. It is difficult to obtain it free from albumen.

Prop. With water it forms a transparent, mucilaginous solution, coagulable by heat at 140°, and more readily still by alcohol and the acids. Myrosin cannot be extracted from the black mustard seed, because of the presence of myronic acid, which, in contact with water, converts it into essential oil.

The *myronate of potassa* is obtained by treating an alcoholic decoction of the mustard cake, freed of its fixed oil by expression, with water, evaporating, separating the mucilaginous substances by alcohol and filtering. By evaporation, the salts form in crystals, which are soluble in water and insoluble in alcohol, and yield on the addition of tartaric acid the—

Myronic acid. It is a non-volatile, colorless, bitter, syrupy mass, soluble in water and alcohol, but scarcely soluble in ether. Prolonged ebullition of its solutions causes decomposition, with the elimination of sulphuretted hydrogen. The soluble salts which it forms with the bases, in contact with myrosin, yield essential oil.

Essential oil. $C_8H_5NS_2$. Does not pre-exist in the seeds, but by distillation with water, is generated under the catalytic influence of myrosin, set free from its combination with potassa or lime. It is necessary to make the powdered seeds into a mash with cold water previous to distillation; the use of hot water at first would coagulate the myrosin, and thus

nullify its influence. Hubatka has found this oil already formed in the horse-radish root; Pleiss found it in the seeds of the *Iberis amara*, *Caprellia Bursa pastoris*, *Raphanus raphanistrum*, and *Sisymbrium officinale*; Wertherin in that of the *Alliaria officinalis*, and Simon obtained it from the scurvy grass (*Cochlearia*). Pleiss's recent researches have also developed it in connection with oil of garlic from the *Thlaspi arvense*, and alone from the *Lepidium rudemale*, *Raphanus sativus*, *Brassica napus*, *Cherianthus annuus*.

The transformation of the oil of mustard into oil of garlic by the action of potassium is effected by the abstraction of the cyanogen and a part of the sulphur, the salt separating being sulpho-cyanide of potassium. (*Gerhardt, Compt. Rendus*, 1845.)

Prop. When pure is perfectly transparent, but as generally obtained has a yellow tinge, which deepens by age. Spec. grav. 1.01. Boils at 298° (*Will*), and gives a vapor of spec. grav. 3.54; dissolves readily in alcohol and ether, from which it is separable by water. With chlorine it unites and disengages hydrochloric acid. Sulphur and phosphorus crystallize from their evaporated solutions in oil of mustard. Concentrated nitric acid converts the essence into yellow *nitro-sinapic* resin, which is insoluble in alcohol and water, and only slightly in ether. By prolonging the action of this acid, oxalic, sulphuric acids, and an uncrystallizable acid are produced. The latter is soluble in water, but insoluble in alcohol and ether. Will and Wertherin consider this essence as a sulpho-cyanic compound, of the radical *Allyl* = C_6H_5 (C_2NS_2). The behavior of oil of mustard towards bases, parting with sulphur and carbon in the proportion of sulphuret of carbon, and forming a series of new bodies with basic properties, presents the greatest analogy with the known comportment of the sulphocyanogen compounds. Among the products which originate in this manner, by the action of metallic oxides on the oil of mustard, is *sinapolin*, already observed by Simon, and formed by the action of barytic water, or recently precipitated hydrated oxide of lead, which separate from the oil of mustard sulphuret of carbon, which however is immediately converted into sulphuretted hydrogen and carbonic acid, so that $2 C_8H_5NS_2$ with 6 PbO and 2 HO give 4 PbS, 2 PbO, CO_2 , and *sinapolin* = $C_{14}H_{12}N_2O_2$, which consequently has taken up HO in the place of CS_2 , which has escaped. Oil of mustard combines directly with ammonia; the compound behaves like an alkali, and has therefore been called *thiosinammin* = $C_8H_5N_2S_2$; the whole of the sulphur can be removed by oxide of lead from the thiosinammin as sulphuretted hydrogen, and in this way a base containing no sulphur obtained, viz. *sinammin*, $C_8H_5N_2$. (*Will. Chem. Gaz.* iii. 253.)

Thiosinammin. The only product of the action of ammonia. It crystallizes, is soluble in alcohol and ether, and more so in hot than cold water. The beautiful yellowish red, crystalline compound which it forms, with platinum, is = $PtCl_3 + C_8H_5$, 2 NS.

Sinamin. Crystallizes in hard, shining, four-sided columns, which, heated to 212°, lose 9.51 pr. ct. of water; again absorbable, however, by

exposure of the cooled opaque mass. The chloride of platinum and sinnamin = $C_8H_6N_2 + 2 ClH$, $2 PtCl_2$.

Sinapolin. Crystallizes in lustrous laminæ, which fuse at 212° . Insoluble in cold potassa solution, but by ebullition therewith, forms oleaginous drops, which dissolve upon the addition of water. From its solutions in the acids, it is separated by ammonia. The aqueous solution is precipitated, like the other bases, by the chlorides of platinum and mercury. According to its formula, it belongs to the benzoyl series, and is oil of bitter almonds + 2 equivs. of ammonia.

The action of an alcoholic solution of caustic potassa upon oil of mustard separates an oily liquid ($C_{28}H_{25}N_3S_4O_4$) of spec. grav. 1.036, and boiling point 419° to 426° . In behavior to metallic salts, it is closely connected with oil of mustard. It is separated by water, and leaves in the residual liquor a potassium compound, of a peculiar, highly remarkable acid. This acid forms a lead compound, ($Pb + C_8H_6NS_4$), it may, therefore, be regarded as the combination of the oil of mustard with sulphuretted hydrogen, and the oily body can be considered as sinapolin with sulphuretted hydrogen. *Will*.

Fixed oil. According to Darby, the fat oil of black mustard seed contains stearic and erucic acids, and a new acid ($C_{35}H_{36}O_4$) in combination with glycerin.

WHITE MUSTARD. The seeds of the *Sinapis alba* contain non-acrid, volatile oil, sulphosinapisin, erucin, myrosin, yellow fat oil, brown resin, gum extractive, lignin, albumen, phosphoric acid, and salt. The absence of myronic acid, or one of its salts, prevents the formation of volatile oil.

Sulphosinapisin. $C_{24}H_{22}NS_2O_7$. A white, crystallizable, bitter, non-acid body, soluble in water, alcohol, and ether. The action of acids, oxides, and salts developes hydrosulphocyanic acid, and under the influence of myrosin, according to Boutron and Fremy, it is transformed into this acid and an acrid substance. This latter is the non-volatile acrid principle not pre-existing in the seed, but readily developed by cold water. It is a reddish, unctuous, pungent, and sulphuretted liquid.

Erucin. (*Simon*.) A yellowish white substance, very soluble in ether, boiling alcohol, carburet of sulphur, and turpentine, but insoluble in water and aqua ammonia. It does not redden the salts of iron, and contains no sulphur.

Fixed oil. Obtained by expression from the seeds of both the white and black mustard. It is reddish yellow, has a mild odor, and thick, oily consistence, and does not easily rancidify. It is soluble in 4 parts of ether and in 1000 parts of alcohol of 0.90. By saponification, glycerin is eliminated, and a soap is formed. The decomposition of the latter yields—

Erucic acid. Form. $C_{44}H_{41}O_3$, HO. (*S. Darby*.) In acicular crystals, melting at 93° , and forms salts. (*Chem. Gaz.* vii.)

MYCOMELINIC ACID. See URIC ACID.

MYRRH. The gummy resinous exudation of the *Balsamodendron myrrha*. In the European markets it is sorted into several sorts or qualities. 1. *Myrrha electa* consists of the selected lumps and tears. 2. *Myrrha in sortis* is com-

posed of the more impure species remaining after the selection of the precious sorts. 3. *Myrrha indica* or *nova*, the irregular fragments. This latter has been examined by Ruicholdt, whose analysis gave—

Essential oil.....	2.183
Resin.....	44.760
Gum (Arabin).....	40.818
Water.....	1.475
Impurities.....	3.862
Carbonates of lime and magnesia...	3.650
Gypsum and perox. iron.....	traces.

Prop. Spec. grav. 1.22 — 1.18. Only partially soluble in water, alcohol, or ether, the former dissolving only the gum, and the two latter the resin and oil. In alkalies it dissolves readily. Nitric acid, after long-continued action, produces an orange-red sediment.

Essential oil (Myrrhole). $C_{22}H_{17}O_2$ (*Ruicholdt*). Light yellow, but thickens and darkens on exposure. Is lighter than water and heavier than alcohol, in which latter and ether it is readily soluble.

Resin (Myrrhin). $C_{21}H_{16}O_3$. Obtained from an alcoholic extract by distilling off the greater part of alcohol, and then evaporating. It is reddish brown, transparent, burns with but a slight residue, and fuses between 194° and 203° . Is neutral and wholly soluble in ether, acetic, and sulphuric acid, and partially in alcohol and boiling caustic potassa. Heated in a glass tube to 334° , it yields an (*myrrhic*) acid resin, $C_{24}H_{16}O_4$. Soluble in ether and alcohol. According to Bley and Diesel, the acid reaction of the water distilled over with the oil, is owing to the presence of formic acid, and not benzoic, as Brandes has announced.

Impurities. Myrrh is often mixed with Indian bdellium (the produce of the *Amyris comiphora*). *Bdellium*, in appearance and taste, is very similar to myrrh, but differs in odor, and is characterized by its great amount of bassorin. Besides this, it is often mixed with another substance, (*opocalpasum*?) for the detection of which Bley and Diesel give directions as follows:

Pseudo-myrrh, which has been frequently found mixed with the genuine myrrh, consists of large pieces of different forms, the majority of them seeming to be fragments of a cylindrical body; they are coated externally with dust, and have a dirty reddish brown color; the surface of fracture is tolerably even, of vitreous lustre, brownish yellow color, and nearly as transparent as Senegal gum. It has a faint myrrh-like odor, and a disagreeable bitter, somewhat balsamic taste. Nitric acid dissolves to a bright yellowish liquid, from which water separates small yellowish particles. Genuine myrrh yields with nitric acid a transparent dirty yellow liquid. *Bdellium indicum* is not dissolved by nitric acid; it softens, becomes whitish and opaque. Bibulous paper, moistened with the alcoholic extract of myrrh and then with nitric acid, acquires the blood-red color first observed by Bonastre; bdellium and pseudo-myrrh exhibit only a yellow or brownish coloring. *Bdellium indicum* is moreover distinguished by its greenish brown color, its more terebinthinate odor, and bitter and somewhat acid taste. It becomes viscous

when held for some time between the fingers. Myrrh yields a bright golden-yellow tincture and an opake whitish residue; pseudo-myrrh, a light yellow tincture and a semi-transparent residue; *Myrrha indica*, a dark yellow tincture and an opake residue. An addition of water produces in the first and last a milky turbidness, and in the second no change. Nitric acid (6 drops to 20 of the tincture) yields with *Myrrha electa* a yellowish white opacity, upon which after a time the periphery of the liquid acquires a bright violet color, while the centre remains yellow. *Myrrha indica* behaves similarly, only that the color is darker; pseudo-myrrh does not exhibit this reaction. Fuming nitric acid produces with the tincture of *Myrrha electa* an umber-brown, and finally a dark violet color; on evaporation, a dark gamboge-colored residue is left; *Myrrha indica* exhibits the same reaction; pseudo-myrrh experiences no change. *Bdellium indicum* and *africanum* are distinguished by their not assuming a violet color on their treatment with nitric acid. About 10 grs. of myrrh, shaken with an ounce of water and filtered, yield with solutions of salts of the oxide of lead a considerable precipitate. *Bdellium indicum*, treated in the same manner, exhibits scarcely any opacity.

MYRICIN. See WAX.

MYRIOSPERMIN. See PERU BALSAM.

MYRISTIC ACID. See MYRISTICA.

MYRISTICA OFFICINALIS. The fruit or nutmeg is encircled by an outer coat of mace.

Nutmeg. Syn. Nux Moschata. Bonastre's analysis gave—

Volatile oil.....	6.0
Liquid fat.....	7.6
Solid fat.....	24.0
Acid (?).....	0.8
Starch	2.4
Gum	1.2
Ligneous fibre	54.0
Loss	4.0

Volatile oil. Obtained by distillation. Is pale yellow, aromatic, and of spec. grav. 0.92, and consists of a light fluid oil and a crystalline principle, heavier than water and fusible below 212°. This stearopten, $C_8H_{16}O_5$, the *myristicin* of John, is volatile, soluble in alcohol, ether, and boiling water, from which latter it crystallizes on cooling.

Butter of nutmegs. Syn. Expressed oil of mace. Consists, according to Playfair, of an essential oil, soluble in cold alcohol, a fat oil, and myricin and coloring matter.

Myristin. Syn. Sericin. Form. $C_{118}H_{113}O_{15} = 4(C_{29}H_{27}O_3) + C_6H_5O_3$ the base. The solid white fat left after the action of cold alcohol upon nutmeg butter; is purified by solution in and crystallization from ether. Fuses at 88°, and is decomposed by solid caustic potassa into glycerin and myristic acid.

Myristic acid. Syn. Sericic acid. $C_{28}H_{27}O_{13} + HO$. Forms solid white lamellæ, fusible between 118° and 120°. A too high heat decomposes it, as also does nitric acid. Soluble in alcohol and ether. Its alkaline salts differ from other soaps by crystallizing from alcohol and forming solutions, which are neither disturbed by aqueous dilution, nor rendered viscid and thready by concentration.

Myristic ether. An oily liquid of spec. grav. 0.864. Formula $C_{31}H_{31}O_4$, but, according to Baudrimont, $C_{32}H_{32}O_4$.

MACE. Henry's analysis gave—Volatile oil, red fat soluble in alcohol, yellow fat insoluble in alcohol, alcoholic extractive, amidin, ligneous fibre, with lime.

Volatile oil. Formula $C_{16}H_{16}O_5$ (Mulder). Colorless, pale yellow, and lighter than water.

MYRONIC ACID. See MUSTARD, OIL OF.

MYROSIN. See MUSTARD, OIL OF.

MYROXILIN. See PERU BALSAM.

MYRTLE WAX. The greenish yellow fat expressed from the boiled berries of the *Myrica cerifera*, and many other species of myrica. It is soft, fusible at 117°, and by saponification yields glycerin and stearic, margaric and oleic acids. When cold, it is solid and brittle, and of spec. grav. 1. By exposure to sun it bleaches.

MYSORIN. *Min.* A massive mineral from Mysore, India, which consists, according to Thomson, of $16.7 CO_2 + 60.75 CuO + 19.5 Fe_2O_3 + 2.1 SiO_3$. If the oxide of iron be an impurity, the mineral has the form. $2 CuO, CO_2$.

N.

NACRITE. *Min.* Several white, unctuous minerals or mixtures have been termed nacrite, which are probably either mica or talc.

NANCEIC ACID. See LACTIC ACID.

NAPHTHA. Syn. Rock oil, Petroleum oil. Is found native, floating upon the surface of water in certain localities in Bavaria and Italy. Spec. grav. 0.753 to 0.836; boiling point 160°. Is inflammable, soluble in alcohol and the oils, and imparts its peculiar penetrating taste and odor to water without being dissolved by it; and when distilled with water, forms no resin and leaves but little residue. With most of the resins and fats, it mixes in all proportions. When very impure, it is semisolid, but liquefies at 80 or 90°, and by distillation yields one solid compound, PARAFFIN, and several carbohydrogens, viz. naphtha, naphthene, naphthole. The difference in their boiling points allows the separation of each. Its adulteration with spirits of terpentine can be detected by adding strong sulphuric acid, which browns and thickens the mixture.

Naphtha. Formula $C_{14}H_{13}$. A nearly colorless liquid. This is the rectified naphtha which, when free of water, is used to preserve sodium and potassium from oxidation. With caoutchouc it forms a gelatinous varnish. Sulphuric and nitric acids decompose it. Chlorine produces an oily body, and iodine dissolves in it. Boils at 185° to 194°.

Naphthene. $C_{16}H_{16}$. Boils at 239°. Is oily and denser than naphtha. Forms compounds with chlorine, iodine, and bromine.

Naphthol. $C_{24}H_{22}$. Boils at 374°. Resembles naphtha in chemical properties.

The mineral naphtha is supposed, from its composition, to have resulted from the action of a high temperature, not exceeding that of redness, upon vegetable matter, and this is highly probable as the destructive distillation of coal yields the above substances. Coal naphtha, however, (obtained by the rectification

of coal tar,) is doubtless a mixture, as it contains, according to Ure, 4.65 pr. ct. of oxygen. It boils too at 316, and has a spec. grav. of 0.857.

Both the native and artificial naphtha are used in the arts, as drying vehicles for paints, and thinning liquids for quick drying varnishes. In some places it is used as an ingredient of burning or illuminating fluids. Wood naphtha, with which it is sometimes confounded, is distinctive in its properties, and is written of under METHYL.

NAPHTHALIDAM. See NAPHTHALIN.

NAPHTHALIC ACID. See NAPHTHALIN.

NAPHTHALIN. A colorless inflammable solid, passing over in crystalline plates along with leucol, pyrrol, kyanol, carbolie, rosolic, and brunolic acids, forming the oily liquid separated by distillation with water from the pitchy residuum of coal tar. These crystals, which also separate from the distilled liquid when cooled to 14°, are pressed and purified by crystallizations from solution in alcohol or ether. It exists also in wood tar.

Prop. Formula $C_{20}H_8$. Insoluble in cold, and only slightly soluble in boiling water. Spec. grav. 1.048; of vapor 4.528; by calculation 4.488. It melts at 175°, and boils at 428°, and condenses unaltered in laminæ.

It is peculiarly the product of a high temperature, and is furnished by alcohol and organic matters in general when heated to redness. *Graham.*

Action of Sulphuric acid. Concentrated sulphuric acid dissolves naphthalin, and transforms it eventually into a semi-solid purplish mass, which, on being dried, leaves scales which are soluble in water and alcohol, and consist of two peculiar acids, the hyposulphonaphthalic, $C_{20}H_8S_2O_5 + HO (?)$, which is crystallizable, and the hyposulphonaphthie, $C_{11}H_4S_2O_5, HO (?)$, which is not crystallizable. *Hyposulphoglutamic acid*, a hard, glassy mass when dry, whose salts are generally soluble, but not crystallizable, is always the effect of the action of vapors of anhydrous. Sulphuric acid upon naphthalin sometimes exists with the two preceding acids. The three differ, and are separable by the unequal solubility and varying crystallization of their barytic salts, which can be formed by diluting the purple mass, before mentioned, with water, and neutralizing it with carbonate of barytes.

When the naphthalin is in excess, and this excess is precipitated by water from its solution in anhydrous sulphuric acid, the precipitate yields on distillation with water a fatty compound, consisting of *sulphonaphthalin*, $C_{20}H_8SO_2 (?)$, a crystalline fusible solid, and *sulphenaphthalide*, $C_{24}H_{10}SO_2 (?)$, a crystalline powder not fusible at 212°. Both are inodorous and insoluble in water, but are separable from the fatty matter by alcohol.

Action of Chlorine. Chlorine, as also bromine, give rise to several products containing these bodies in different proportions.

The chlorine compounds are, according to Laurent,

1. The *Chlorhydrate of Chloronaphthalase*, $C_{20}H_7Cl + HCl$, a yellow oil, denser than and insoluble in water, which, on treatment with potassa, loses HCl and gives *chloronaph-*

thalase, $C_{20}H_7Cl$. When the oil, formed by the action of chlorine and warmth upon the fluid chloride of naphthalin, is distilled, it yields *chloronaphthalin*, $C_{20}H_5Cl_3$, which crystallizes from ether in colorless soft prisms, fusible at 163.4°.

2. The *Chlorhydrate of Chloronaphthalase*, $C_{20}H_6Cl_2 + H_2Cl_2$. Formed by the action of chlorine at 140°. Fuses at 320°, and crystallizes from ether. When distilled or treated with an alcoholic solution of potassa, *chloronaphthalase*, $C_{20}H_6Cl_2$, a crystallizable solid, fusing at 111.2, is formed. This latter again is transformed by chlorine, at the ordinary temperature, into *chlorhydrate of chloronaphthalase*, $C_{20}H_4Cl_4 + H_2Cl_2$, which fuses at 105.8°, and may be sublimed without change.

These chlorine compounds, when boiled in nitric acid, gave to Laurent several new bodies. Thus from $C_{20}H_7Cl + HCl$ is formed a yellow crystalline neutral body, *oxichloronaphthalose*, $C_{20}H_5O_3Cl_2 = C_{20}H_4Cl_2O_2 + HO$, insoluble in water, and fusing at 206°. By farther treatment with nitric acid, *chloronaphthalosic*, $C_{20}H_4ClO_3 + O_2$, and *naphthalosic* $\frac{1}{2} (C_{16}H_4O_4 + O_2)$ acid, as also *oxichloronaphthalenose*.

Naphthalic or Phthalic acid, $C_{16}H_4O_6$, 2 HO, formed by the action of nitric acid and warmth upon chloride of naphthalin ($C_{20}H_6Cl_2 + H_2Cl_2$), together with a *volatile*, transparent liquid ($CCl + NO_4$) of spec. grav. 1.685 at 59°, soluble in alcohol and ether. Naphthalic acid yields silky crystals, by sublimation, which fuse at 221°, are difficultly soluble in water, and forms salts with the bases. Ammonia transforms the anhydrous acid into *phthamide*, $C_{16}H_6NO_5$.

Action of Nitric acid. Hot nitric acid gives rise to several compounds, varying in their proportions of nitric acid. 1. *Nitronaphthalase (nitronaphthalid)*, $C_{20}H_7 + NO_4$, dropping from its alcoholic solution in yellow crystals, which fuse at 109.5°. When heated with lime, it gives yellow crystalline *naphthalase*, $C_{20}H_7O$, which tinges oil of vitriol beautifully blue. 2. *Nitronaphthalase (nitronaphthdehyd)*, $C_{20}H_6 + 2 NO_4$, a yellow crystalline powder, insoluble in water and alcohol, and fusible at 365°.

By the further action of nitric acid upon the mother waters, additional compounds are generated. All, however, are unimportant, but though distillable without decomposition, are apt to explode when suddenly heated. The reaction, sometimes very violent, which ensues when naphthalin is placed in contact with bichromate of potassa, water, and sulphuric acid, results in a peculiar compound.

Naphthalidam. $C_{20}H_9N$. Formed by the action of sulphuretted hydrogen, with or without ammonia, upon nitronaphthalase. It is a powerful base, which melts at 86°, boils at 582° and crystallizes in white needles. Its salts are crystallizable. When heated it remains liquid to 32°, and in this state absorbs oxygen by exposure and becomes violet. Zurin, its discoverer, has found that the other nitrogenized derivatives of naphthalin by similar treatment give analogous bases.

From the foregoing reactions of chlorine and nitric acid, it may be inferred that naphthalin is composed of two carbohydrogens, $C_{16}H_4 + C_4H_4$, one of which, the latter, is more readily alterable.

NAPHTHENE. } See NAPHTHA.
NAPHTHOLE. }

NAPLES YELLOW. A mixture of 3 lbs. lead, 2 lbs. antimony, and 2 oz. alum and salt, calcined, ground, and elutriated to a fine powder. Used as a pigment and in enamelling.

NAPOLEONITE. See FELDSPAR.

NARCITIN. A white, deliquescent solid, extracted from the several varieties of the Narcissus. It is soluble in water, alcohol, and the acids.

NARCOTIN. *Chem. Syn.* Derosne's salt. Exists in opium and the milky juice of several of the Papaveraceæ.

Prep. It can be directly extracted from opium by ether, or from the impure morphia precipitated by ammonia from an aqueous decoction of opium. The best method, however, is to treat the residual opium, exhausted by water, with acetic acid, adding water, and precipitating the filtered liquid with ammonia. The narcotin purified by crystallization from boiling alcohol, is in transparent prisms or needles, but when precipitated is in a white, light powder.

Prop. A weak base; is soluble in ether, alcohol, and the oils; insoluble in water and the alkalies; melts at 338° with a loss of 0.04 of its weight, but concretes again at 266°, into a crystalline mass, if cooled slowly. A higher temperature decomposes it. Its characteristics as to solubility, property of not being blued by the sub-salts of iron, or reddened by nitric acid, nor by sulphuric ether unless containing traces of nitric, serve to distinguish it from morphia, with which it is frequently mixed.

Its solutions give no alkaline reaction; and though it dissolves in acids, the salts thus formed are mostly acid and difficultly crystallizable. They are all soluble in alcohol and ether, and readily decomposed by water, tannin, and ammonia. The muriate, sulphate, and acetate are the most common. The latter is precipitated from its acetic solution as a neutral salt by subacetate of potassa.

There is a diversity of opinion as to the correct formula for narcotin. Liebig gives $C_{40}H_{20}NO_{12} = 4681$, and another chemist $C_{48}H_{24}NO_{15} = 5645$; but the recent researches of Blythe have perhaps more correctly stated it as $C_{46}H_{23}NO_{14}$, and its equivalent 5339.

Derivatives. Wöhler's (*Chem. Gaz.* ii. 249) valuable researches show that narcotin, when exposed in the presence of an acid to oxidizing influences, is decomposed into a non-nitrogenous acid (*opianic*), an organic base (*cotarnin*), and carbonic acid.

Opianic acid. Crystallizes in slender, colorless prisms, and consists of $C_{20}H_8O_9 + HO$. It is more soluble in hot than cold water, and forms soluble salts with the bases which crystallize. This acid is not volatile, and melts at 284° without loss of water, but by a higher heat, though unaltered in composition, is rendered insoluble in water, alcohol, and even dilute alkalies. The *opianic ether* = $C_4H_5O + C_{20}H_3O_9$.

Opiammon. $C_{46}H_{17}NO_{16}$ (?). A light yellow powder, probably colorless when pure, obtained by cautiously heating opianate of ammonia at or near 212°, until ammoniacal vapor ceases to escape. It is insoluble in water, but dissolves

when heated with it to 302°. It melts readily, but is not volatile, and is unalterable by dilute hot acids.

Xanthopenic acid. Formed by the action of alkalies upon opiammon, and is characterized by the yellow color of its salts. It is a lemon-yellow crystalline powder, soluble in alkalies.

Opianosulphurous acid. $C_{20}H_6O_7 \cdot 2SO_2 + HO$. A product of the action of sulphurous acid on opianic acid left as a crystalline, transparent mass, when the mixture or solution of the two are gently evaporated. Its lead and barytic salts are crystalline and brilliant.

Sulphopianic acid. $C_{20}H_8O_7S_2$. Generated by the prolonged action of sulphuretted hydrogen upon opianic acid dissolved in water, at 158°. A yellow powder separates; when heated, it becomes amorphous and transparent, and at 212° liquefies. It dissolves in alcohol, and under certain circumstances crystallizes from the solution in minute yellow prisms.

Hemipinic acid. $C_{10}H_4O_5 + HO$. Formed by the higher oxidation of opianic acid. Crystallizes in colorless prisms, which lose their 2 equivs. of water below 212°. Melts at 356°, and sublimes unaltered. Is more soluble in water than opianic acid, and forms an easily soluble crystalline salt with ammonia. Those of lead and silver are insoluble.

Cotarnin. $C_{26}H_{13}NO_5$, or, according to Blythe, $C_{25}H_{13}NO_6$. Formed at the same time as opianic acid. Is dark yellow and crystalline, readily soluble in alcohol and water. Its muriate is amorphous, and the solution of it is precipitated by tannin, as also by the chloride of platinum and of mercury. The double platinum salt is reddish yellow and crystalline; that of mercury also crystalline, but pale yellow. Both dissolve in hot water, and perhaps are modified by its prolonged action.

Humopinic acid. Whether its formula is $C_{45}H_{23}O_{17}$ or $C_{46}H_{20}O_{14}$, has not yet been determined. A dark brown, amorphous substance generated by the decomposition of narcotin at 428°. Is insoluble in water and dilute acids, but dissolves in alcohol, imparting a yellow-red color, and in alkalies, giving yellow solutions.

Apophyllenic acid. Probably a product of the decomposition of cotarnin. Its crystals lose their water below 212°, and become milk-white. Both its ammonia and silver salts crystallize, the latter in grouped acicular forms.

In addition to the above products, Marchand mentions *narcotein*, an uncrystallizable coloring matter, resulting from the action of nascent oxygen upon narcotin. It is but slightly soluble in ether, but readily so in alcohol and water, with which latter it forms a yellow solution. The continued action of nascent oxygen transforms the narcotein into opianic acid.

Narcotic acid. Formed by the action of hydrate of potassa upon narcotin. The change effected is probably due to the separation of the elements of water by the reassimilation of which narcotin is again formed, as all attempts to isolate it have failed. It is isomeric with narcotin, or differs from it only by 1 or 2 equivs. of water. The narcotate of potassa is readily soluble in alcohol, and is left by evaporation therefrom as an amorphous mass.

Blythe also obtained the opianic and hemipinic acids and cotarnin, by the reaction of an excess

NARCEIN.

of perchloride of platinum upon narcotin. If the platina salt is in less proportion instead of cotarnin, a new base, intermediate between it and narcotin is formed. This body, *narcogenin*, ($C_{36}H_{19}NO_{10}$) is found only in combination with the platina salt, which compound crystallizes in long, orange-yellow needles, and unlike the corresponding combinations of narcotin and cotarnin, is completely decomposed by the action of ammonia and warmth.

Sulphonarcotide. $C_{16}H_{18}N_2SO_{16}$. Formed by the action of excess of sulphuric acid upon narcotin, (*Journ. de Pharm.*, 1848, p. 302.) and according to Laurent, belongs to the same class of substances as the amides and anilides. It is a dark green powder, soluble in alcohol and boiling water.

NARCEIN. See OPIUM.

NATIVE ANTIMONY. *Min.* Spiessglanz. Cryst. Hexagonal, rhombic; cleavage splendid, parallel to end plane; usually massive, lamellar. $H. = 3 - 3.5$. $G. = 6.65 - 6.72$. Color and streak tin-white; metallic; rather brittle. Very fusible, evolving fumes, even after removing it from the flame, and depositing oxide of antimony on the coal. It is metallic antimony, Sb.

NATIVE GOLD, COPPER, &c. See GOLD, COPPER, &c.

NATROCALCITE. See CALCAREOUS SPAR.

NATROLITE. See MESOTYPE.

NATRON. *Min.* Cryst. Oblique rhombic; usually in effloresced crusts. $H. 1 - 1.5$. $G. = 1.4$. White, often tinged with foreign matters; taste alkaline; effloresces in the air, and effervesces with acids. It is essentially $NaO, CO_2 + HO$. From the soda-lakes of Egypt, &c. See TRONE.

NECRONITE. See FELDSPAR.

NEEDLE ORE. *Min.* Acicular bismuth glance. In acicular crystals, and massive. $H. = 2 - 2.5$. $G. = 6.125$. Blackish lead-gray, with pale copper-red tarnish; metallic; opaque. It fuses readily, fumes and coats the coal white and yellow while a bismuth-like bead remains; gives with soda a globule of copper; decomposed by nitric acid. Form. $3 Cu_2S, BiS_3 + 2 (3 PbS, BiS_3)$. It occurs at Beresof Siberia.

NEEDLE SPAR. See ARRAGONITE.

NEEDLE STONE. See MESOTYPE.

NEMALITE. *Min.* Fibrous; fibres easily separable, elastic. $H. = 2$. $G. = 2.35 - 2.44$. White, with gray, bluish, or yellowish tint; silky. Form. $(MgO, CO_2 + HO) + 5 (MgO, HO)$. It occurs at Hoboken, opposite N. Y., Piermont, Rockland Co., N. Y.

NEPHELIN. *Min.* Syn. Rhomboidal feldspar, somnite, davyne, cavolinite, elæolite, giesseckite. Hexagonal, prismatic; also columnar, massive. $H. = 5.5 - 6$. $G. = 2.5 - 2.64$. White or yellowish, dark green, greenish or bluish gray, brownish or brick-red; vitreous, greasy; transparent, opaque.

Nephelin fuses with difficulty to a blebby glass; borax dissolves it with difficulty; cobalt solution gives a grayish blue on the fused edges. Elæolite fuses readily; mic. salt decomposes it with great difficulty; cobalt solution colors the fused edges blue. Both are decomposed by acids, the silica gelatinizing. Form. $3 RO, SiO_3 + 3 (Al_2O_3, SiO_3)$; $RO = \frac{1}{2} NaO + \frac{1}{2} KO$. The general form. is that of

NICKEL.

Indianite, Wehrlite, Lepidornelan. Found in lavas of Vesuvius, zircon-sienite of Norway, Ilmen, Ural, &c. See DAVYNE.

NEPHRITE. *Min.* Jade, Beilstein, Massive. $H. = 6.5 - 7.5$. $G. = 2.93 - 3.02$. Leek-green, passing into blue, gray, and white; vitreous; translucent, subtranslucent; very tough, with splintery fracture, infusible. Several minerals, tremolite, &c. have been included under nephrite. The form. is probably $3 RO, 2 SiO_3$, in which $RO = MgO, CaO, FeO, MnO$. True jade is from Turkey and China.

NEROLI, OIL OF. Obtained by distillation from the orange flowers (*Citrus aurantium*). When recent, it is nearly colorless, but reddens on exposure. In contact with platinum black, it yields a peculiar acid. (*Dobereiner*.) It consists of two oils, one reddened by sulphuric acid and soluble in water, and the other insoluble and of less agreeable aroma. Boullay separates stearopten by dissolving the oil of neroli in a small portion of 90 pr. et. alcohol. This camphor melts at 122° , is insoluble in water, slightly soluble in absolute and boiling alcohol, but readily in ether.

NERVES. According to L'Heretier, the nerves contain more albumen, less solid and more soft fat than the BRAIN. On boiling the nerves in alcohol, a fluid fat exudes, which sinks to the bottom of the vessel; on boiling them with water they swell, but do not dissolve. The albumen of the medullary portion dissolves in a weak solution of potassa, the fat swims on the surface, and the neurilemma remains. On treating the nerves with acetic acid, the medullary portion is expressed by the contraction of the tubes, which are themselves unacted upon. *Simon*.

The "nerves are the conductors and propagators of mechanical effects in the body." Nervous matter, Liebig thinks, must be formed in the animal body, either by depriving protein of some azotized product, or by adding to fat an azotized compound; and he has suggested that the power of the vegetable alkalies to affect the nervous system may be owing to their composition, which approaches nearer to that of nervous matter than any other compounds. These alkalies may promote or check the formation of nervous matter, and thus produce their peculiar effects.

NEUTRALIZATION. The destructibility of the characteristic properties of either acids or bases, by the addition of one to the other, in proportional equivalents to form neutral compounds.

NEUTRAL SALTS. Those combinations in which the equivalent proportions of base and acid are equal; thus, for instance, ZnO, SO_3 . Among the haloids, $NaCl$ is an example of a neutral salt, the halogen and metal being one to one.

NEWKIRKITE. *Min.* Black, metallic, square prisms. $H. = 3.5$. $G. = 3.824$. It consists of oxides of manganese and iron, with water. From Elsass.

NICKEL. *Chem. Tech.* A grayish white metal, discovered by Cronstedt in 1751. It exists as sulphuret in the magnetic pyrites of Alsuda, in Sweden; as arseniuret in *kupfer-nickel*; as oxide, sulphuret, and antimoniosulphuret in other minerals. It is also a consti-

NICKEL.

tuent of meteoric iron, and of several minerals of Missouri, and of other States. It is generally obtained from *speiss*, an artificial arseniuret, prepared from the native compound, and usually containing 50 pr. ct. and upwards.

Nickel is very liable to contain a little cobalt, that metal being almost always an associate, and its separation very difficult. Spec. grav. 8.279, and when forged 8.666. Ductile, malleable, and magnetic, but loses the latter property at 630°. Carbon unites with it, and increases its fusibility. In the arts its chief use is as a component of German silver or Chinese *PACKFONG*. See ALLOYS and ARGENTAN. Eq. 369.68 O. = 100 or 29.62 H. = 1. Nickel forms with oxygen three compounds, as follows:

Protoxide. NiO. Obtained as hydrate by precipitating a salt of nickel with caustic alkali. Calcination of the nitrate yields the anhydrous oxide. Is green when hydrated, gray when anhydrous. The former gives a blue solution with ammonia, but neither is taken up by soda or potassa. Heated in contact with hydrogen gas, it is reduced to metal. With the strong bases it acts as an acid, and as a base with alumina, peroxide of iron, &c.

Sesquioxide. Ni₂O₃. Prepared by digesting hydrated protoxide in the solution of a chlorite, or by heating the nitrate below redness. Is a black, indifferent body, not soluble (unaltered) in acids or alkalis. Heat and oxygen transform it into protoxide.

Peroxide. The existence of this oxide has not yet been positively determined. As obtained by Thenard, it is a dirty green, changeable body.

Sulphuret. NiS. The protosalt is obtained by direct combination. Grayish yellow, metallic lustre, and soluble in nitric acid and in aqua regia. The hydrated protosulphuret is made by passing a stream of sulphuretted hydrogen into a neutral salt of nickel until complete precipitation. Deep brown, and soluble in strong HCl acid and in an excess of sulphuretted hydrogen. Arfwedson's subsulphuret, 2 NiS, is obtained by heating sulphate of nickel to redness in contact with hydrogen.

Bisulphuret. NiS₂. Prepared by calcining at low red heat a mixture of sulphur and carbonates of nickel and of potassa, and washing the resulting mass with water. A steel gray powder.

The salts of nickel are all of the protoxide, and those which are soluble from green solutions. The anhydrous salts are yellowish. All the nickel salts are decomposable by heat, though some exert a greater resistance than others. Sulphuretted hydrogen gives no precipitate in acid solutions, but hydrosulphuret of ammonia throws down black sulphuret, slightly soluble in an excess of the reagent.

HALOID SALTS.

Chlorine. Nickel forms with chlorine both a hydrated and anhydrous compound. The first is obtained by evaporating the solution of the oxide or carbonate in HCl to crystallization; the latter by passing dry chlorine over the metal heated to redness, or by slightly calcining the hydrated chloride. The anhydrous salt is soluble in water by prolonged ebullition, imparting a green color. It absorbs ammonia

NICKEL HYDRATE.

and forms a compound, of the formula NiCl, 3 NH₃ (*Rose*), which, when heated, is resolved into metallic nickel. The hydrate forms emerald-green, efflorescent crystals.

Iodide. NiI. Crystallizes with 6 equivs. of water, and its aqueous solution, by heat, yields an oxyiodide, NiI (3 NiO) 15 HO. *Erdmann*.

OXYSALTS.

Sulphate. NiO, SO₃. Green crystals which lose transparency by gentle heat. Very soluble in water, insoluble in alcohol and ether. Lose water of crystallization by exposure, and become ultimately yellow. There is a subsulphate in green powder and insoluble in water.

Sulphate of Nickel and Potassa. KO, SO₃ + NiO, SO₃. Crystallizable and soluble in nine parts of cold water.

Nitrate. NiO, NO₃. Bluish green crystals, efflorescent in dry and deliquescent in moist air. Soluble in water and alcohol. With ammonia it gives bright blue soluble crystals, of the composition NiO, NO₃ (2 NH₃) HO.

Carbonate. An apple-green, basic hydrate, forming a salt with ammonia. By calcination in open vessels, it is changed to sesquioxide.

Silicate. Exists native in certain minerals.

Chromate. A deliquescent red salt, which forms a double compound with ammonia.

NICKEL BLOOM. *Min.* Nickelocker, nickelblüthe, in capillary crystals, and massive. Soft; apple-green. Yields water in a tube, gives arsenical odors on coal, and a bead which shows nickel and cobalt. Soluble in acids. Form. 3 NiO, AsO₃ + 8 HO, which corresponds to COBALT BLOOM. From Riechelsdorf, Hessa, Kamsdorf, near Saalfeld, Allemont, Dauphiny, Chatham, Connecticut. It is a good surface indication of arsenical nickel ores.

NICKEL BISMUTH GLANCE. *Min.* Cryst. Regular; cleavage 8-hedral. H. = 4.5. G. = 5.13. Steel-gray to silver-white; metallic; brittle; fuses on coal to a brittle, magnetic globule, giving a bismuth coating, and with fluxes the reactions of nickel. Soluble in nitric acid, showing the presence of bismuth upon dilution with water. The best form. proposed is that of Frankenheim, NiS, BS₃ + 6 (NiS, N₂S₃.)

NICKEL GLANCE. *Min.* Nickelarsenikies, nickelantimonglanz. Cryst. Regular, cube, 8 and 12-hedron, and pentagonal 12-hedron; cleavage cubical; lamellar, granular. H. = 5 — 5.5. G. = 6.097 — 6.45. Silver-white with grayish-black streak; metallic; brittle. Decrepitates in a closed tube, sublimes sulphuret of arsenic, and shows the presence on coal of arsenic and nickel; decomposed by nitric acid. The most probable form. is NiS₂ + NiSb for nickel antimony glance, and NiS₂ + NiAs for nickel arsenic glance, the Ni being sometimes replaced by Fe and Co. But 1 eq. arsenic or antimony is two atoms; so that in this view the general form. may be Ni (S, Sb, As)₂. Wackenroder's analysis of a nickelglance from Oelsnitz, in Voigtland, led to the form. NiS₂ + 2 NiAs.

Local. Loos, Helsingland, Sweden; Harzgerode, on the Hartz; Nassau. See COBALT GLANCE.

NICKEL HYDRATE. *Min.* Amorphous, incrusting, chromic iron, from Texas, Lancaster Co., Pennsylvania. H. = 3 — 3.25. G. =

3.05. Emerald green; vitreous; streak yellowish green. In a tube yields water; becomes blackish by heat; in the fluxes gives the reactions of nickel, and the metal is obtained by reduction with soda; soluble in muriatic acid. Form. NiO , 2 HO. *B. Silliman, Jr.*

NICKEL PYRITES. See COPPER NICKEL.

NICOTIANIN. } See TOBACCO.

NICOTIN. }

NIGRIN. See RUTILE.

NIHIL ALBUM. The old title of flowers of ZINC.

NIOBITE. *Min.* Columbite. G. Rose has shown that it is isomorphous with Wolfram.

NIOBIUM. *Chem.* A new metal, in the form of a blackish powder, discovered by Rose in the Tantalites of Bavaria, and deriving its name from Niobe, daughter of Tantalus, in reference to its similarity and that of its oxide to Tantalum. (*Comptes Rendus*, 1844.) When heated, it becomes oxidized into—

Niobic acid. It is obtained by heating in an ammoniacal current the chloride saturated with ammoniacal gas. The metal is insoluble in aqua regia, but dissolves in a mixture of fluohydric and nitric acids.

Niobic acid resembles tantalic acid. When heated, it becomes yellow, but whitens again on cooling. Cold sulphuric acid precipitates it entirely from the solution of a niobate. When mixed with charcoal and heated to redness in chlorine, it is changed into chloride.

The chloride is white and infusible. Water converts it into hydrochloric and niobic acids. Hermann (*Chem. Gaz.* v. 409) obtained the chloride (NbCl_2) in pinnately grouped prisms. The formula of the crystallized niobate of soda is NaO , $\text{NbO}_2 + 7 \text{HO}$. *Hermann.*

NITRATE OF LIME. *Min.* Efflorescent, white, silky tufts, in the nitre caves of Kentucky, India, &c. It is frequently associated with the

NITRATE OF MAGNESIA, which presents white, deliquescent efflorescences.

NITRATE OF SODA. *Min.* Soda-salt-peter. Cryst. Hexagonal, rhombic; usually in efflorescences. $\text{H.} = 1.5 - 2$. $\text{G.} = 2.1 - 2.29$. White, variously tinted; transparent; soluble in water; taste saline, cooling. It deflagrates less violently than nitre, is more deliquescent and soluble in water. It is essentially NaO , NO_5 , mingled with sulphate and muriate of soda, &c. A large formation of this salt, in beds of several feet thickness, over a space of 40 leagues length, occurs in Tarapaco, N. of Chili. It is largely used in the manufacture of nitric and sulphuric acids.

NITRE. *Min.* Salt-peter. Cryst. Right rhombic; usually in crusts. $\text{H.} = 1$. $\text{G.} = 1.937$. White; subtransparent; soluble with a sharp saline and cooling taste; deflagrates on burning coals. It is essentially nitrate of potassa, KO , NO_5 . From salt-peter caves in Ceylon, Spain, Hungary, Egypt, Kentucky, &c. Used in the manufacture of gunpowder.

NITRIC ACID. }

NITRIC OXIDE. } See NITROGEN.

NITRIFICATION. The EREMACAUSIS of substances containing nitrogen. During this decay, ammonia is constantly being formed, and the oxidation of this ammonia constitutes the phenomenon. The formation of nitrates

in soils is said to be owing to this process, for as porous substances have the property of condensing the ammonia of the atmosphere and always contain water, the essential conditions of nitrification are supplied. When alkaline bases are present, the nitric acid generated unites with them to form nitrates. See MOULD.

NITROBENZULE. See BENZYL.

NITROGEN. *Chem.* Syn. Azote. A gas, one of the constituents of the ATMOSPHERE, discovered by Rutherford in 1772. Exists also in a large number of organic matters. It takes the name of azote from α and $\zeta\omega$, two Greek words, signifying destructive of life, that being one of its properties.

Prep. By passing a current of air, freed of moisture and carbonic acid, over copper heated to redness. It may also be obtained by burning phosphorus in air confined under a bell glass.

Prop. Symb. N. Equiv. 175. O. = 100 or 14. H. = 1. Spec. grav. 97200. A colorless, permanent, inodorous gas. Soluble in water to the extent of .016 of its volume. Forms five compounds with oxygen, as follows:

Protoxide. Nitrous oxide. NO. Prepared by heating nitrate of ammonia in a retort. A colorless, inodorous gas of spec. grav. 1.527; liquefies at 0° under a pressure of about 30 atmospheres, and solidifies at 100° below 0° . (*Comptes Rendus*, 1848.) Bodies which burn in air give a flame of greater brilliancy in this gas. From its property of imparting a pleasant sensation of intoxication, when respired in a state of purity, it is termed exhilarating or laughing gas. If the gas contains air or other impurity, the respiration of it is dangerous.

Deutoxide. Nitric oxide. NO_2 . Is generated by the action of nitric acid, of spec. grav. 1.2, upon copper filings. A colorless gas of spec. grav. 1.039, which, on exposure to air, absorbs oxygen, reddens, and becomes NO_4 . Is not very favorable to combustion.

Nitrous acid. NO_3 . Obtained by passing through an U tube, kept cool by a freezing mixture, a gaseous mixture of 4 vols. of deutoxide of nitrogen and 1 vol. of oxygen. It is also frequently a product of the action of nitric acid upon organic matters. Is more readily obtained in combination with bases. Combines with certain acids, the sulphuric acid compound being crystalline, and of spec. grav. 1.831. It mixes with cold water, but decomposes upon slight elevation of temperature.

Hyponitric acid. Peroxide of nitrogen. NO_4 . Prepared by the dry distillation of nitrate of lead, previously powdered and thoroughly desiccated. An orange liquid of spec. grav. 1.42. Boils at $+83^\circ$, and congeals at -6.8° . It gives off a deep, ruddy, corrosive vapor, of spec. grav. 1.72. By contact with water, it is decomposed into nitric and nitrous acids.

Nitric acid. Azotic acid, aquafortis. NO_5 . Prepared by decomposing salt-peter in a retort by sulphuric acid, and collecting the acid which is eliminated in a cooled receiver. For manufacturing upon a large scale, the retorts are cylindrical and of cast iron, three or more forming a range to be heated by one furnace. The front of each cylinder is fitted with a

movable head for the convenience of charging and emptying. After the charge of nitre has been introduced, the mouth is to be closed and fastened by bolts and lute. The acid is added by means of a funnel through a hole in this head, at other times kept tightly closed by means of a stopple. The acid gas eliminated by the action of sulphuric acid upon the nitre has vent at the opposite end of the retort through a tube adjusted for the purpose, and so bent as to lead into a series of blue stoneware Wolff's jars in which it is condensed. The acid thus made contains sulphuric and muriatic acids, but is sufficiently pure for the ordinary purposes of the arts. For use in analyses, however, it must be redistilled with a solution of nitrate of silver. Nitrate of soda, or cubic nitre as it is called, is more economical than nitre for the production of this acid, and hence is the article most used for the purpose.

Owing to its great affinity for water, the anhydrous acid is obtained only with great difficulty, and by treating nitrate of silver with absolutely dry chlorine. It crystallizes in brilliant six-sided prisms, melting at 85° and boiling at 113° . Precaution is necessary in handling this substance, as it is liable to explosion under certain circumstances. (*Déville Comptes Rendus*, 1849.) Its aqueous combinations are definite hydrates, as follows:—

1. $\text{NO}_5 + \text{HO}$. Colorless when pure, but yellow on exposure to light. Congeals at -58° . When added to water, heat is developed and ruddy fumes appear, a property to which this hydrate owes its name of *fuming acid*.

2. $\text{NO}_5 + 4 \text{HO}$. More stable than the preceding, neither decomposable by light, nor by repeated distillation. When distilled with its own weight of concentrated sulphuric acid, three-fourths of its water is abstracted, and $\text{NO}_5 + \text{HO}$ is formed.

Properties of Nitric acid. Is colorless or yellow, according to its state of purity. The strongest acid boils at 187° , and has a spec. grav. of 1.522, but the density decreases as the proportion of water is augmented. The facility with which it parts with a portion of its oxygen to many substances, renders it an energetic oxidizing agent, and very useful in effecting decomposition of organic matters and chemico-solutions of metals. Of a large class of salts which it forms with bases, the most important are the nitrates of potassa, soda, lead, silver, and strontia.

Nitrogen and Hydrogen. These two gases unite to form AMMONIA.

Nitrogen and Carbon. See CYANOGEN.

The table below is useful for showing the per centage of water in acids of different densities.

Specific Gravity.	Real acid in 100 parts of the Liquid.	Specific Gravity.	Real acid in 100 parts of the Liquid.	Specific Gravity.	Real acid in 100 parts of the Liquid.	Specific Gravity.	Real acid in 100 parts of the Liquid.
1.5000	79.700	1.4189	59.775	1.2947	39.850	1.1403	19.925
1.4980	78.903	1.4147	58.978	1.2887	39.053	1.1345	19.128
1.4960	78.106	1.4107	58.181	1.2826	38.256	1.1286	18.331
1.4940	77.309	1.4065	57.384	1.2765	37.459	1.1227	17.534
1.4910	76.512	1.4023	56.587	1.2705	36.662	1.1168	16.737
1.4880	75.715	1.3978	55.790	1.2644	35.865	1.1109	15.940
1.4850	74.918	1.3945	54.993	1.2583	35.068	1.1051	15.143
1.4820	74.121	1.3882	54.196	1.2523	34.271	1.0993	14.346
1.4790	73.324	1.3833	53.399	1.2462	33.474	1.0935	13.549
1.4760	72.527	1.3783	52.602	1.2402	32.677	1.0878	12.752
1.4730	71.730	1.3732	51.805	1.2341	31.880	1.0821	11.955
1.4700	70.933	1.3681	51.068	1.2277	31.083	1.0764	11.158
1.4670	70.136	1.3630	50.211	1.2212	30.286	1.0708	10.361
1.4640	69.339	1.3579	49.414	1.2148	29.489	1.0651	9.564
1.4609	68.542	1.3529	48.617	1.2084	28.692	1.0595	8.767
1.4570	67.745	1.3477	47.820	1.2019	27.895	1.0540	7.970
1.4530	66.948	1.3427	47.023	1.1958	27.098	1.0485	7.173
1.4500	66.155	1.3376	46.226	1.1895	26.301	1.0430	6.376
1.4460	65.354	1.3323	45.429	1.1833	25.504	1.0375	5.579
1.4424	64.557	1.3270	44.632	1.1770	24.707	1.0320	4.782
1.4385	63.760	1.3216	43.835	1.1709	23.910	1.0267	3.985
1.4346	62.963	1.3113	43.038	1.1648	23.113	1.0212	3.188
1.4306	62.166	1.3110	42.241	1.1587	22.316	1.0159	2.391
1.4269	61.369	1.3056	41.444	1.1526	21.519	1.0106	1.594
1.4228	60.572	1.3001	40.647	1.1465	20.722	1.0053	0.797

NITROLEUCIC ACID. See PROTEIN.

NITRO-MECONIC ACID. See MECONIN.

NITRONAPHTHALASE. See NAPHTHALIN.

NITROSACCHARIC ACID. See *Glycicoll* under GELATIN.

NITROUS ACID. See NITROGEN.

NITROUS ETHER. See ETHYL.

NITROUS OXIDE. See NITROGEN.

NOMENCLATURE. The older names of substances formed by the chemist were arbitrary, so that those allied in their composition received distinct names, which did not point out their relations. When the present nomenclature was established, towards the close of the 18th century, facts and substances had increased to such an extent, that the memory would have been burdened by the multitude of names required. Hence, the important principle of the new system of naming compounds: to express more or less their composition.

This principle was carried out successfully, and was doubtless one cause of the more rapid advance of the science. But the reaction, that is, the multiplication of facts and substances, has been so great, that, at the present time, it has been found necessary to depart from the main principle. Thus the names of sulphuric and sulphurous acids were designed to convey the idea that the former was a higher compound, or contained more oxygen than the latter, and the names, sulphate and sulphite, for the salts of these acids, were equally precise. But when an acid was found intermediate between these two, and another below the sulphurous in its content of oxygen, the terms hyposulphuric and hyposulphurous were respectively applied to them. Recently, however, several acids have been found below the sulphurous, and the term hypo (below) had to be abandoned, and the terms dithionous, trithionous, &c. were substituted for these acids.

When the present nomenclature was established, the doctrine of definite proportion in compounds was very imperfectly understood, and hence this important element of naming compounds was left out of view. Thus the name, sulphuric acid, although conveying something more of the composition of the body than the older terms, oil of vitriol, vitriolic acid, &c. did not give its precise composition, but merely informed us that it contained sulphur, and by inference oxygen, on the then theory that oxygen was the acidifier. It did not give us the least hint that it consisted of 1 equiv. of sulphur + 3 equivs. of oxygen, and yet to follow out their main principle, it should have done so, or, at least, when the doctrine of proportion was subsequently developed and fully settled, the name should have been so modified. There was therefore a radical defect in the system of nomenclature, which renders it very ill-adapted to the present more advanced state of the science.

But the difficulties of establishing a system of names, expressive of composition, have been greatly increased by the astonishing strides which organic chemistry has made, through and from the labors of Chevreul in organic chemistry during the past 30 years, by the development of isomerism and isomorphism; and hence it is that empirical names are now generally adopted for organic substances. We cannot turn over a single volume of a chemical journal, now issuing, without being struck, perhaps alarmed, at the number of new compounds, which are piled upon our previous stock, and which, unhappily for us, make heavy drafts upon an already overburdened memory. Facts have advanced much more rapidly than sound generalization, so that it is almost as easy to remember a substance or an isolated fact as to make a proper disposal of it in the mental storehouse, according to its generic relations. Add to these difficulties the conflicting and fanciful theories of modern chemists,—urged rather by imagination and sometimes a lower kind of ambition than by a sincere desire to relieve the mind of over-taxation,—and we must acknowledge that the present system of nomenclature must be abandoned, in order to give the true science of chemistry a rapid and onward impulse.

Were it not for the admirable system of formula-notation, introduced and perfected by Berzelius, the science would not have received the acceleration which we have witnessed; and by holding strenuously to this system, the science will advance in spite of the heavy load of isolated facts it has to bear. The difficulties of reading chemical works are increased by the varying views as to the H_1 or H_2 , but when a chemist chooses to halve carbon, for some reason which appears to him satisfactory, he is little aware of the vast burden he is imposing on the rest of the chemical world, and the notoriety which he gains by the change is little less than that of him who burned the Ephesian temple of Diana. Changes must and will come, and are even desirable, but such all-grasping changes should not be adopted until their principles have been most thoroughly sifted and approved.

NONTRONITE. See HALLOYSITE.

NOSEAN. See HAUVE.

NORIUM. *Chem.* The radical of a new earth, found by Svanberg in the Zircons of Norway and Sweden.

NOVACULITE. *Geol.* A silicious, almost compact clay-slate, employed for hones.

NUCLEUS OF CRYSTALS. See CRYSTALLIZATION.

NUSSIERITE. *Min.* Cryst. Hexagonal, in obtuse rhombs; usually in mammillary masses. $H. = 4$. $G. 5.04$. Yellow, greenish, or grayish; lustre greasy, feeble; yellowish white streak. It fuses to a white enamel, and gives with borax a yellowish glass; soluble in nitric acid. It appears to be $PbCl + 5 (3 PbO, PO_5)$ in which PbO contains a portion of CaO and FeO , and PO_5 contains also AsO_5 . See ARSENIOPHOSPHATES. From Beaujeu, Dpt. Rhone.

NUTTALITE. Is probably SCAPOLITE.

NUT-GALLS. See GALLS.

NUTMEG. See MYRISTICA.

NUX VOMICA. The seeds of the *Strychnos nux vomica*, analyzed by Pelletier and Caventou, gave—STRYCHNIC or Igasuric acid, STRYCHNIN, BRUCIN, wax, fat oil, gum, starch, lignin, yellow coloring matter, and lime and potash salts. The bark of the tree contains gallate of brucin, but no strychnin.

O.

OAT. A cereal grass, the seeds of which are valuable as feed for horses and cattle. There are several varieties, of which the most common is the *Avena sativa*, or common oat.

According to Vogel, in every 100 pts. there are 40 of bran and 60 of farina, and the percentage composition of this latter is—

Greenish yellow fat oil.....	2.00
Bitter extractive.....	8.20
Gum	2.50
Grayish albuminous substance.....	4.30
Fecula	59.00
Water and loss.....	24.00

Norton (*Silliman's Journal*, 1847) gives the following comparative view of the composition of the ash of the different parts of the ripe and dried plant:—

OBSIDIAN.

ODORIN.

*Comparative View of the Quantity of Ash yielded by the different Parts of the Plant.
Calculated dry.*

	Hopeton, North- umberland.	Hopeton, Fife.	Potato, North- umberland.	Dun, Edinburgh.	Sandy, Fife.	Mean of each part.
Grain.....	2.14	1.81	2.22	2.11	1.67	2.00
Husk	6.47	6.03	6.99	8.24	6.03	6.75
Chaff	16.53	17.23	18.59	19.16	18.97	16.09
Leaf.....	8.44	7.19	14.59	10.29	15.92	10.88
Top straw.....	4.95	5.44	9.22	8.25	11.01	7.77
Middle straw.....	6.11	5.23	7.41	6.53	9.01	6.66
Bottom straw	5.33	5.18	9.76	7.10	7.30	6.93

*Comparative View of the Composition of Ash from each of the above Parts in Hopeton Oats,
from Mr. Harbottle, Hexham, Northumberland.*

	Grain.	Husk.	Chaff.	Leaf.	Top straw.	Middle straw.	Bottom straw.
Sulphuric acid.....	—	9.61	5.32	14.80	16.33	18.45	13.29
Phosphoric acid.....	49.19	1.04	—	—	—	—	—
Chloride of sodium.....	0.35	0.24	5.11	2.29	3.13	3.03	15.36
Phosphates of lime, mag- nesia, and iron.....	—	—	5.84	6.13	2.84	3.03	0.78
Potash }	31.56	10.26	7.96	14.89	19.09	21.80	43.17
Soda }	—	—	—	—	—	—	—
Lime.....	5.32	1.95	4.53	6.99	7.02	7.23	6.06
Magnesia	8.69	0.38	1.84	2.55	2.84	2.91	2.07
Peroxide of iron	0.88	1.58	0.24	—	0.30	1.40	0.61
Peroxide of manganese.....	—	0.92	—	—	—	—	—
Soluble silica	0.89	4.46	11.99	5.90	5.13	7.34	5.03
Insoluble silica	0.98	68.39	56.05	45.75	43.31	33.14	12.25
	97.86	98.83	98.90	99.30	99.99	98.33	98.35

The proximate constitution of the organic part of the dry plant, as ascertained by the same chemist, is—

	Hopeton Oats, Northumberland.	Hopeton Oats, Ayrshire.	Hopeton Oats, Ayrshire.	Potato Oats, Northumberland.
Starch	65.24	64.80	64.79	65.60
Sugar	4.51	1.58	2.09	0.80
Gum.....	2.10	2.41	2.12	2.28
Oil	5.44	6.97	6.41	7.38
Casein (avenine).....	15.76	16.26	17.72	16.29
Albumen	0.46	1.29	1.76	2.17
Gluten	2.47	1.46	1.33	1.45
Epidermis	1.18	2.39	2.84	2.28
Alkaline salts and loss...	2.84	1.84	0.94	1.75
	100.00	100.00 F.	100.00 F.	100.00

OBSIDIAN. *Geol.* A volcanic rock from ancient and modern active volcanoes, called by different names, and having a differing composition. Some of the names are Pearlstone, Pitchstone, Volcanic glass, Marckanite, Sphernelite. It contains 60—80 silica, 2—13 alumina, 0—6 soda, 0—8 potassa, together with oxide of iron, lime, magnesia, water, &c.

OCHHRAN. A kind of BOLE.

OCHRE. *Tech.* BROWN HEMATITE mixed with aluminous and other substances, passes into yellow ochre. There are probably contained in all ochres organic substances, such as the crenic and apocrenic acids of Berzelius, but they have received little investigation. Ochre is employed as a pigment.

OCHROITE. See CERITE.

OCTAHEDRITE. See ANATASE.

ODOR. A term used in describing a few

minerals, such as argillaceous, that peculiar smell perceived when clay is breathed on; bituminous, the odor of bitumen and of some coals when heated; fetid, a disagreeable smell produced by friction of some varieties of quartz, &c. It is an unimportant character in describing the external characters of minerals, but is important in determining them by their behavior before the blowpipe, whether they emit the odor of burning arsenic, sulphur, or selenium.

The smell emitted by a body being peculiar to itself, generally serves as one of its distinctive characteristics. It generally arises from the presence of volatile matter naturally existing in the body, or generated by decomposition, or that of impurities with which it may be admixed.

ODORIN. See PICOLIN.

CENANTHAL. *Chem. Syn.* Cēnanthole, Cēnanthylc aldehyde, Hydruret of cēnanthyl. A colorless, very fluid, strongly refractive, aromatic, volatile liquid, obtained by distilling the seeds of the *Palmi Christi* with water. It also forms one of the products of the oxidation of stearic and margaric acid, and other analogous fatty bodies, by nitric acid. Bussy and Lecanu give $C_{14}H_{14}O_2$ as its formula. Its spec. grav. is 0.8271 at 44°, and when free from water it boils between 307° and 316°, but after continued ebullition becomes colored and acid. Alcohol and ether dissolve it readily, water very sparingly. Its crystalline hydrate, $C_{14}H_{14}O_2 \cdot HO$, on exposure, absorbs oxygen and becomes cēnanthylc acid.

Met-cēnanthole. *Syn.* Cēnanthylc metaldehyde. An isomeric modification of cēnanthole, obtained by the action of nitric acid upon it in the cold. It is an inodorous body, solid at 50° to 53°, and below that point crystallizable and not acid. When it has been exposed for some time to a temperature higher than 59° to 60°, it loses its power of solidifying, but regains it by a long exposure to a moderate degree of cold. *Bussy & Lecanu.*

CENANTHIC ACID. *Chem.* From *ovos*, wine, and *αβος*, flower, because of the aroma which it imparts to wines. Formula $C_{14}H_{13}O_2$, HO . When distilled it becomes anhydrous and loses HO , and acquires higher boiling and fusing points. In a free and pure dry state, the hydrated acid has the consistence of butter; the fused anhydrous, at 87-8°, becomes solid; at a higher temperature changes into a colorless, tasteless, inodorous oil, which reddens litmus and readily dissolves in caustic and carbonated alkalies, forming two series of salts—acid and neutral. Alcohol and ether dissolve it readily, but it is insoluble in water.

Cēnanthic acid is mostly found in combination as *cēnanthic ether*, forming by its smell and taste the distinguishing test of wines, to all of which it is common, from other fermented alcoholic liquids. According to Fauré, the bouquet of wines is due to a small quantity of volatile oil. It can be separated by treating the ether with potassa, and decomposing the resultant salt by sulphuric acid. The eliminated acid swims to the surface as an oily liquid.

Cēnanthic Ether. *Syn.* Cēnanthate of the oxide of ethyl. Form. $C_{14}H_{13}O_2$, C_4H_5O .

Prep. Obtained by treating the oily products of the distillation of wine lees, with solution of carbonate of soda, to remove free (cēnanthic) acid, and removing the small remnants of water and alcohol by digestion with chloride of calcium.

Prop. A colorless liquid, of the odor of wine, spec. grav. 0.862, boiling point between 437° and 446°. It is almost insoluble in water, but very soluble in alcohol and ether. It is decomposed by the caustic, but not so readily by the carbonated alkalies.

CENANTHYLIC ACID. *Chem. Syn.* Azoleic acid. Formula $C_{14}H_{14}O_4$ (*Bromérs*), $C_{12}H_{14}O_4$ (*Tilley*), $C_{12}H_{12}O_4$ (*Larivière*). A colorless, aromatic, inflammable liquid, formed on the oxidation of wax, stearic acid, and other fatty bodies (particularly castor oil), by nitric acid. It boils at 298.5°, and decomposes at a higher temperature.

OERSTEDTITE. *Min. Cryst.* Quadratic. $H. = 6.5$. $G. = 3.629$. Brown, splendent. Yields water in a tube; infusible; dissolves with difficulty in the fluxes; insoluble in soda. It consists of $\frac{2}{3}$ titanate of zirconia, and $\frac{1}{3}$ of a silicate $3 RO, 2 SiO_3 + 9 HO$, in which $RO = CaO, MgO, FeO$. Årendal, Sweden.

OILS. *Chem. Tech.* Oils are of that class of FATS which retain their fluidity to 50°; though there are some that remain liquid at much lower temperatures, and a few which are solid at some degrees higher. They have an unctuous feel and consistency, are lighter than water, and immiscible with it, except by the intervention of some agent producing an Emulsion. The specific gravity of oil increases with age, and the frequent discrepancies in the same kind of oil is owing to the difference of locality or cultivation of the plant which yields it, and the varied mode of extracting the oil. They are combustible and nearly all soluble in ether, and more or less so in alcohol, though the solvent power, says Saussure, increases in a ratio corresponding with that of their content of oxygen.

Oils, by congelation, low temperatures, and pressure of the concrete mass, yield a liquid and a solid portion. The former consists of OLEIN, and the latter of MARGARIN, which is the characteristic solid component of vegetable fats, though in some few STEARIN is also said to have been found.

All oils have the same ultimate composition, viz., carbon, hydrogen, and oxygen. The small quantity of nitrogen occasionally found in some vegetable oils is doubtless due to albuminous or other nitrogenous impurity. When distilled at high temperatures they are partially decomposed, and give as products carburetted hydrogen gas, acrolein, sebacic acid, and a variety of isomeric compounds, with carbonaceous matter as residue. When hot they are good solvents of sulphur and phosphorus, iodine and chlorine, the two latter, however, immediately becoming hydriodic and hydrochloric acids, respectively, and by their reaction converting the oils to a waxy consistence.

Generally speaking the oils are divided into *Fixed* or *Fat*, and *ESSENTIAL OILS*. This, however, is an incorrect classification, for the latter, though in one physical condition, that of greasiness to the touch, analogous, are otherwise both in properties and composition entirely dissimilar. The more proper arrangement would be into vegetable and animal oils, and in this order we will treat of them.

VEGETABLE OILS.

Many plants yield two kinds of oil, one properly so called, and which is termed fixed in contradistinction to the other, which being volatile at 212° and less, is styled essential oil. The latter, as above stated, belongs to an entirely different class of substances, and so we confine our remarks to the vegetable oils proper.

Many of the vegetable oils, especially when properly and cleanly prepared, are employed as aliments. Those which are not thus applicable are used in the arts as soap ingredients, and for illumination and lubricating the joints of machinery; the siccative oils, however, be-

ing mostly employed as vehicles for pigments. The oil of ben (*MOHRINGA OPTERA*), which is clear and inodorous, is of frequent application in perfumery.

Fixed Vegetable Oils. These exist in the seeds of the plant, sometimes in the fleshy pulp of the fruit, and rarely in the root. They are contained in that part of the seed which gives birth to the cotyledons, and not in the plumula or radicle; and of all the families of plants the cruciform is richest in oleiferous seeds. The seeds should be ripe, fresh, and of good quality. The quantity of oil which they yield is always less than they actually contain, and the amount of oil remaining in the *marc* or pressed cake is always greater in proportion as the starchy, ligneous, and albuminous constituents are more abundant. The mode of ascertaining the exact quantity of oil in oleaginous seed is easily practised: it is only necessary to bruise and repeatedly treat a given quantity of seed with ether. This dissolves out the oil, and when evaporated in a capsule over a water-bath, leaves the oily matter. This latter, when purified, by water, of soluble matters, then dried and weighed, gives the exact proportion of oil contained in the seeds.

All the fixed vegetable oils remain unaltered in closed vessels, and all on exposure lose more or less of their liquidity. Some experience this change by the absorption of oxygen to such extent as to solidify when acted upon in thin strata. These latter, by way of distinction termed *siccative* or *drying* oils, are richer in olein, which has several characteristics peculiar to itself. The former, which under the same circumstances only thicken and rancidify, are styled non-drying oils. According to Saussure the absorption of oxygen is as great in eight summer days as in eight winter months, and the phenomenon is attended with the evolution of carbonic acid proportionally in amount to that of the oxygen taken up, but there is no water formed. The rapid absorption of oxygen creates a high elevation of temperature, and to this cause may partly be attributed the frequent spontaneous ignition of greased wool, cotton, rags, &c. The diffuse surface, which the many points of the cotton presents, facilitates the oxidation or resinification of the oil, and the intensity of heat thus eliminated is such as to inflame the hydrogen of the oils, and thus produce combustion.

Jonas's *Caoutchouc of Oils*, so called from its properties analogous to India rubber, is an elastic body, partially soluble in ether and wholly so in spirits of turpentine, obtained by subjecting the drying oils to a high heat, and boiling the residue in water acidulated with nitric acid. (*Millon's Annuaire*, 1847, p. 509.)

Manufacture. Most of the fixed vegetable oils are separated by expression. The process consists of several steps succeeding each other in order, as follows:—

1. The cleansing of the seeds.
2. The crushing and bruising of the seeds.
3. The torrefaction of the seeds either by the naked fire or steam.
4. First pressure.
5. Second crushing of the seeds.
6. Second torrefaction.
7. Second pressure.

The cleaning is effected by fanning the seeds, which separates all the foreign matters. The bruising is requisite in order to facilitate the separation of the oil, which is yielded more readily when the seeds are in a pasty state. There are two machines used for this purpose: the first bruises the seeds so as to prevent their slipping through the stones which finish the grinding. It consists of two well-turned hollow cylinders which run with equal celerity, and are so arranged as to enable their adjustment at any required distance from each other. The motive power is applied to one of the cylinders, and is thence transmitted by means of cog-wheels to the other. A wooden hopper kept constantly filled with seeds is so arranged as to furnish a continual supply to the rollers beneath. The bruised seeds are then subjected to the action of a pair of vertical chasers, which are mounted upon a common axletree fitting into a notch in an upright beam, so that they may ascend or descend proportional to the resistance they encounter.

Some seeds, when bruised, yield readily to pressure, and give what is termed a virgin oil, of agreeable taste. In other seeds, however, especially those which are rich in mucilage, the oil is so tardy of separation that the paste must, previous to pressure, undergo torrefaction, in order to coagulate the albumen, and by thus rendering the oil less viscous, facilitate its separation. Torrefaction, it is true, impairs both the savor and color of oils; but when carefully managed by an experienced hand, the danger of any change is almost entirely obviated. Torrefaction is practised in two ways: first, in metallic vessels either over the naked fire or with a water-bath intervening; and secondly, in an appropriately constructed apparatus heated by steam. The first method is attended with so many disadvantages and inconveniences as to be of very limited use.

Pressing. The grain thus heated and bagged is now ready for pressure, and for that purpose is transferred to the press. There are two separate pressings requisite. After the first, the bags are emptied, and their contents a second time crushed and heated previous to the last bagging and pressure. The oil of the second runnings is of a quality inferior to the first. As the product of oil is to a certain extent proportional to the intensity of the pressure, it is more economical to employ that kind of apparatus which gives the most power. The wedge press is much used for this purpose, but that of hydraulic power is far preferable.

Of the hydraulic presses, the horizontal form is most advantageous, and for the second pressing there is frequently a lining steam chest to facilitate the expulsion of the last particle of oil.

For the mode of extracting oils from fruits, see *OLIVE OIL*.

ANIMAL OILS.

These oils are not found in a liquid state, but are extracted by pressure from the solid fats. They consist mainly of olein, and differ from the vegetable oils in having a less wider range of employment. Not being siccative, they are unfit for paints, and those only which are free of smell will serve as soap ingredient. Most of them are used for illumination and lubricat-

ing machinery. Their modes of manufacture and general properties are given under the heads of LARD and SPERMACEI.

Action of Alkalies. All the fixed oils, whether of vegetable or animal origin, are capable of union with potassa and soda, though some are more readily saponified than others. The resulting compounds are called SOAPS. The combinations of oil with metallic oxides form the medicinal *plasters*.

Ammonia, according to Boullay, produces effects different from those of the fixed alkalies. The action of ammoniacal vapor gives amides of the fat acids. The *margaramide* which he thus obtained from olive oil is a white, crystalline, neutral, inflammable solid, readily soluble in alcohol and ether, but insoluble in water. It melts at 140° , and has the formula $C_{34}H_{33}O_2, NH_2$ = anhydrous margarate of ammonia less one equiv. of water.

Action of Acids. The action of the acids upon oils has been the subject of many recent critical examinations. The results so far obtained are, however, only partial. We give here only the general influence of the acids upon the oils, and refer to each oil for its respective behavior to and transformations by them. Those acids whose radicals are nitrogen, chlorine, and bromine, are easily decomposed by the oils. The changes which result from the action of acids vary with the kind employed.

Sulphuric Acid. Strong sulphuric acid in proportions exceeding 50 pr. ct. transforms them into unctuous, pasty compounds (*Savons acides*) which give a lather with, and are soluble in water. When but one or two per cent. of oil of vitriol is added, there is no action upon the oil, for the acid, in preference, attacks its parenchymatous and mucilaginous impurities, and either by partially carbonizing or rendering them insoluble, precipitates the coloring matters, and thus improves the limpidity of the oil. In larger quantities its influence is limited to the elimination of the fatty acids, and the abstraction of the GLYCERIN of the oils, and its union therewith as *sulphoglyceric acid*; a greater excess gives *sulphoily* (*sulpholeic* and *sulphmargaric*) acid.

Nitric Acid. All oils are not uniformly influenced by this acid, for its action varies with the oil upon which it operates. Most probably its action is confined to the OLEIN component, for the products into which it transforms that body are not yielded by margarin or stearin. Some chemists, nevertheless, hold a contrary opinion, among them Caillot, who obtained both butyric and formic acid by the oxidation of stearin with nitric acid, gradually added, until the disappearance of the margaric acid, which is formed during the earlier stage of the reaction. (*Millon's Annuaire*, 1846, p. 342.)

Nitric acid transforms the non-drying oils into suberic and numerous volatile acids; nitrous acid converts them into elaidin. The drying oils, on the contrary, are not solidified and transformed, and hence this behavior, and their greater richness in olein serve to distinguish them from the drying oils.

Adulteration of Oils. The practice of adulterating the higher priced oils with those of inferior quality has become so prevalent as to

render necessary some decisive method of detecting these frauds.

M. Heidenreich has found, by the application of a few drops of sulphuric acid to a film of oil, upon a glass plate, a means of ascertaining its purity. The glass plate should be laid upon a sheet of white paper, and a drop of the acid let fall on the middle of ten drops of the oil to be tried. This information will be particularly valuable, for in the purchase of stock, the dealer will find himself necessitated to resort to it frequently for protection against fraud, as the practice of sophisticating oils has of late become extensively prevalent.

With the oil of rapeseed and turnip seed a greenish blue ring is gradually formed at a certain distance from the acid, and some yellowish brown bands proceed from the centre.

With oil of black mustard, in double the above quantity, also a bluish green color.

With whale and cod oil a peculiar centrifugal motion, then a red color increasing gradually in intensity, and after some time it becomes violet on the edges.

Olive oil, pale yellow into yellowish green.

Oil of poppies and sweet almonds, canary yellow, passing into an opaque yellow.

Oil of linseed, a brown magma, becoming black.

Of tallow or olein, a brown color.

In testing oils, a sample of the oil imagined to be present should be placed alongside of the actual oil, and both should be compared in their reactions with the acid. A good way of approximating to the knowledge of an oil is by heating it, when its peculiar odor becomes more sensible.

If the drop of acid which has been added is agitated with a glass rod, the reactions are different. The rape and turnip seed oils then assume a uniform brown color, without mixture of red; with from 5 to 6 drops of acid the color is of an opaque brownish red, and the edges of the mixture become green. The oil of black mustard produces the same reaction with from 5 to 6 drops of acid, but the color is still more opaque. Whale and cod oil directly become of a brownish red, and then pass to a violet color free from any tinge of green. If from 5 to 6 drops of acid are added, the color is brighter and the violet shade is sooner apparent. The oils of olive, poppy, and sweet almonds become more or less grayish yellow. Linseed oil changes into a brownish black, resinous mass. Olein assumes a dirty brown color. (*Journ. für Prakt. Chem.* 1842.) In these tests it is important to observe what colors are developed at the commencement of the reaction, and then compare them with those produced by a similar operation upon an oil of standard purity.

Lamot, a chemist in Paris, finds that colza oil (analogous to rapeseed oil) may be tested, relative to its sophistication with cheaper vegetable oils, by the increase of density which they impart to it; this becomes very evident when the several oils are heated to the same pitch. The instrument which he calls an *oleometer* is merely an hydrometer with a very slender stem. He plunges it into a tin cylinder filled with the oil, and sets this cylinder in another containing boiling water. His oleometer

is so graduated as to sink to zero in pure colza oil heated as above, and he finds that it stops at 210° in linseed oil, at 124° in poppy seed oil, at 83° in fish oil, and at 136° in hempseed oil—all of the same temperature. By the increase of density, therefore, or the ascent of the stem of the hydrometer in any kind of colza oil, he can infer its degree of adulteration.

The presence of a fish oil in a vegetable oil is readily ascertained by agitation with a little chlorine gas, which blackens the fish oil, but has little or no effect upon the vegetable oil.

Lard and lard oil, Ure says, are not at all darkened by chlorine.

A specific gravity bottle or globe, having a capillary tube-stopper, would make an excellent oleometer upon the above principle. The vessel should be filled with the oil and exposed to the heat of boiling water until it acquires a temperature of 212° F., and then weighed. The vessel with the pure colza oil will weigh several grains less than with the other oils similarly treated. Such an instrument would serve to detect the smallest adulterations of sperm oil. Its spec. grav. at 60° F., when pure, is only 0.875; that of southern whale oil is 0.922 or 0.925; and hence their mixture will give a spec. grav. intermediate, according to the proportion in the mixture. Here is a key to the detection of admixture of oils, especially when they differ in their specific weights. Ure says he was enabled by it to discover sperm oil in pretended lard oil.

According to Heidenreich, every oil which is derived from the same plant, or the same animal, has at the same temperature a density which hardly varies but in the thousandths.

The density of the oils which have been examined under this point of view is comprised between 0.900 (olein), taking water at 59° F. as unit, and 0.961 (castor oil). These two limits correspond to the 66th and 34th degrees of Gay-Lussac's alcoholometer. Consequently knowing the degree of the alcoholometer which a pure oil indicates, we may ascertain the adulteration of a mixed oil, and we may even judge within certain limits of the degree of adulteration, for the common oils which are most usually employed for this purpose present a great difference of density.

This last method, which is generally employed in commerce, immediately shows the adulteration of an oil; and when the action of the sulphuric acid is added, it is impossible to be deceived as to the nature, and indeed hardly as to the quantity of the foreign oil mixed with a given oil. We give as example the density of two oils:—

Name of the Oil.	Specific Weight.	Degrees of Gay-Lussac's Alcoholometer.
Olein (tallow oil)	0.9003	66
Purified whale oil.....	0.9231	55½

(*Journ. für Prakt. Chem.*, Aug. 1842.)

Purification of Oils. Many oils, and particularly the fish oils in their natural state, are always more or less impure, and some of them too viscous to be used without purification. These impurities consist mostly of resinous, albuminous, gelatinous, and coloring matters. When separated from these, the oil is more fluid, less colored, and better adapted for

illumination and uses in the arts. One of the methods practised for purifying fish oils is to thoroughly incorporate them with a hot infusion of oak bark, and then, after repeated steamings and washings with hot water, to let it percolate through bone-black. In this way the albumen and gelatin are removed. Another plan is to subject the oil in deep vessels to the action of steam, blown in and continued for twelve or more hours, and then after the deposition of the impurities to draw off the clear, supernatant, oily stratum. In the *Franklin Institute Journal* for 1843 are some remarks upon the purification of fish oils, by Girardin and Preisser. They cite the following as the methods in most general use:—

“In various scientific and technical works we find processes for the purification of fish oils, which, although simple, are useless, and rather tend to mislead those engaged in their sale or purification.”

Thus, Mr. Davidson of Edinburgh purifies oil by treating it with 1 pr. ct. of chloride of lime, diluted with water under violent agitation, and he assures us that the odor is entirely destroyed; but we obtain only a bleached and thick matter, which is clarified by adding 85 grms. of sulphuric acid diluted with 16 or 20 times its weight of water. The mixture is stirred, gently boiled, and, after filtering warm, is suffered to cool and repose for several days. MM. G. & P. repeated this process without any satisfactory result.

The *Journal hebdomadaire des Arts et Metiers* points out several processes for the same purpose. The first consists in mingling 28 grms. pulverized chalk and 42 grms. slaked lime with a gallon of the oil, stirring well, and adding 0.236 litre water; after 2 or 3 hours of repose it is mixed again, and this operation repeated for 2 or 3 days; 28 grms. of common salt dissolved in 0.710 litre water is then added, the mixture stirred at intervals for two days, suffered to settle, and the oil drawn off.

Another process in the cold, applicable to cod oil, consists in putting into 4½ litres of the oil, previously prepared by the preceding process, 28 grms. of chalk; then, after twenty-four hours, 28 grms. of potash dissolved in 113 grms. water; and finally, after several hours, 57 grms. common salt dissolved in 473 grms. water. After settling a few days, the oil is drawn off.

Neither of these processes is sufficient, as MM. G. & P. have satisfactorily ascertained. The same journal asserts that the oil is obtained so pure by the following process, that it can be employed in woollen manufactures.

Put into 4½ litres (1 gallon) of impure oil 35 grms. chalk, an equal amount of slaked lime, and 0.473 litre of water; after stirring and a repose of several days, add 0.473 litre water and 85 grms. potash; heat the liquid without bringing it to boiling, and draw it off when the oil has a light amber color; it has now only a pungent, fatty odor. Finally, add 0.473 litre water, containing 28 grms. salt, and after boiling the mixture for half an hour, turn off the oil into a reservoir. This process does not refine the oil.

Many English patents for the same purpose were tested by MM. G. & P. One treats fish oils in the cold by bone black, in small frag-

ments, and filters through animal charcoal after repeated agitation. Such a process clarifies the oils, and removes a portion of their empyreumatic odor, but does not in the least diminish their essential odor.

Another method, recently published in France, has succeeded no better. It consists in pouring into the oil a solution of bichromate of potash, mixing thoroughly, then adding a solution of oxalic acid. The action is energetic, but after repose and drawing off, the oil still retains its characteristic odor.

There is a process among the French patents, which consists in heating the oil merely to simmering with 10 pts. of water for 5 or 6 hours, and towards the close of heating adding a milk of 1 pt. of water with one-twelfth of chalk and one-twelfth of lime. After settling perfectly it is drawn off and run into reservoirs through carded wool or pounded charcoal. This process clarifies the oils, but decolorizes them imperfectly, and does not at all remove their odor.

At Rouen they refine whale oil by sulphuric acid, as in operating on seed oils; but this method removes neither color nor odor. If, previous to this operation, it be stirred for some hours with chalk, and a current of steam be passed through it, a bleached liquid is obtained, which, by the addition of a suitable quantity of sulphuric acid, deposits plaster on settling. The clear oil, filtered through animal black, has lost a portion of its deep color, and has not a strong odor; but it is not perfectly purified, even after many successive filtrations.

The oxygenation of oils leads to very bad results. MM. G. & P. remark that oils filtered and treated, whether by chlorides, lime, chalk,

or animal charcoal, and then left to themselves for 30 or 40 days, deposit a bleached organic substance, soluble in water and ether, analogous to margarin, and, while depositing, the oil is more and more decolorized. Fish oil may be obtained of a quality resembling fine olive oil in appearance, by exposing it to the sun, then to the action of chloride of lime, and filtering several times through animal charcoal. The odor is lessened, but not entirely removed. A simple exposure to the sun for several months determines an abundant deposit, while the oil is clarified and sensibly purified.

If whale oil be brought in contact with caustic lye, employed cold and in small quantities, the decolorization is hastened; the mass separates into two distinct strata; the upper one, decolorized, is very fluid and limpid, but always odorous; the lower, which is very small, is a mixture of the alkaline solution strongly colored brown, and of all the solid portion of whale oil analogous to margarin. It is not necessary to submit the decanted oil to any other process of purification; in this state it is suitable for all manufacturing purposes, excepting on account of its odor, which is always well defined.

It appears from the experiments of MM. G. & P. on fish oils, that we at present possess no sufficiently efficacious means of removing their strong and disagreeable odor. The best method, at present, is to submit them either to the action of alkalies or to the successive action of chalk, steam, and sulphuric acid; to suffer them to repose, and filter several times through animal charcoal. We thus obtain a clear oil, less colored, and of a less repugnant odor; but its want of odor is out of the question.

Table of the principal Vegetable Fat Oils.

Oils.	Plant whence derived.	Specific Gravity.	Congealing Point.
Linseed.....	<i>Linum usitatissimum</i>	0.9347	81.5
Filbert (nut).....	<i>Corylus avellana</i>	0.9260	
Walnut (nut)	<i>Juglans regia</i>	0.9283	81.5
Poppy	<i>Papaver somniferum</i>	0.9243	64.4
Hemp	<i>Cannabis sativa</i>	0.9276	81.5
Olive	<i>Olea Europæa</i>	0.9176	39 to 41
Almond.....	<i>Amygdalus communis</i>	0.9180	50
Ben.....	<i>Guilandina mohringa</i>		
Beech	<i>Fagus sylvatica</i>	0.9225	63.5
Mustard.....	<i>Sinapis nigra</i>	0.9160	
Sunflower.....		0.9262	
Rapeseed	<i>Brassica Napus</i>	0.9136	39
Castor	<i>Ricinus communis</i>	0.9611	
Plum kernel.....	<i>Prunus domestica</i>	0.9127	
Cocoa-nut.....	<i>Cocos nucifera</i>		
Palm	<i>Cocos butyracea</i>	0.968	
Cotton seed.....	<i>Gossypium barbadense</i>		
Colza (turnip).....	<i>Brassica campestris (oleifera)</i>	0.9136	42.8
Cherry kernel.....	<i>Prunus cerasus</i>	0.9239	
Peach kernel.....			
Horse-chestnut.....	<i>Æsculus Hippocastanum</i>	0.927	
Cameline	<i>Myagrurn sativum</i>	0.9243	64.4
Indian cress (Nasturtium)	<i>Lepidium sativum</i>		
Galeopsis	<i>Galeopsis ladanum</i>		
Julian violet.....	<i>Hesperis matronalis</i>		
Grapeseed.....			
Cardamom	<i>Elettaria cardamomum</i>		
Bays.....	<i>Laurus nobilis</i>		
Croton.....	<i>Croton tiglium</i>		

Purification of Vegetable Oils. Much of the mucilage, and especially the suspended matters, separate after repose; but in order to completely clarify the oil, it must be agitated with one-half to 2 pr. ct. of sulphuric acid of 66° B., afterwards well mixed with water, and allowed to rest for some days; the clear supernatant portion is then to be drawn off, and the lower stratum filtered through woollen bags. The application of steam heat facilitates the process. (The direct application of steam suffices, of itself, to completely purify and whiten many animal oils.) To separate any residue of water that may be retained by the oil, an addition of chalk in sufficient quantity to saturate the acid is necessary, and this treatment should take place after the water and impurities have settled.

For particulars as to the treatment of oils and their application in the arts, see *Knapp's Technology* and *Morfit's Applied Chemistry*.

OILS, VOLATILE AND ESSENTIAL. See ESSENCES.

OIL GAS. See Illuminating Gas.

OIL OF VITRIOL. See Sulphuric acid under SULPHUR.

OILY ACIDS. *Chem.* Syn. Adipose, saponic acids. The natural acids of oils and fats are so called. Those which are fixed may be separated by saponification. To eliminate the volatile acids, subsequent distillation is requisite. See OILS, MARGARIN, OLEIN, and the several fatty bodies. By reference to the series of fat acids under FORMULA, it is evident that C_2H_2 , or a multiple of it may be regarded as the conjugate throughout the series, the lowest member of which is formic acid. The late researches of Kolbe and Frankland indicate a radical in each of the acids above the formic, composed of $CnHn - 1$, as acetyl C_2H_3 ; but even in this view, these radicals contain C_2H_1 , paired with a multiple of C_2H_2 . (J. C. B., *Journ. Frank. Inst.* 1848.)

OINTMENT. *Phar.* A mixture of fat or oil and wax, and sometimes resin, and used in pharmacy, in its simple state, as a mild dressing for blisters and sores, or as a vehicle for other substances which are to be applied to the body externally as rubefacients or eschars.

Deschamps advises the addition of 120-00 grammes of powdered benzoin to every 3000-00 of melted fresh lard, as preservative of the whiteness of the resultant ointment and preventive of its tendency to rancidify, or to become altered by the alkaline reaction of any body that may enter into its composition.

According to the same authority, ointment in which $\frac{1}{8}$ th poplar buds have been fused, resists oxidation better than all other fatty bodies. (*Chem. Gaz.* i. 663.)

OSANITE. See ANATASE.

OKENITE. *Min.* Dysclasis, fibrous. H. = 4.5 — 5. G. = 2.28 — 2.36. White, with a shade of yellow or blue; often opalescent; subtransparent, subtranslucent; very tough; doubly refractive. Yields water in a tube; fuses in the pincette to a white enamel; difficultly soluble in the fluxes, gives a colorless bead with soda, which becomes opaque on cooling. Decomposed by muriatic acid. Form. $3CaO, 4SiO_3 + 6HO = 3(CaO, SiO_3 + HO) + (SiO_3, 3HO)$. From Disco, Greenland, and the Faroe Islands.

OLANIN. A base of unknown properties, found by Anderson in animal empyreumatic oil.

OLEFIANT GAS. See ELAYL.

OLEIC ACID. See OLEIN.

OLEIN. *Chem.* A natural compound of oleic acid with oxide of GLYCERYL, and forming the more liquid constituent of FATS and fat OILS. Spec. grav. .913 at 59°.

Prep. To one part of melted lard add 7 or 8 parts of hot alcohol of .798 spec. grav., and renew this treatment until complete solution ensues. Upon repose, the solid constituents crystallize out and leave the olein in solution. Distil off $\frac{2}{3}$ of the alcohol, and add water to the residue. The oil swims on the top and can be drawn off. To separate any residual portion of solid matter, it should be cooled and filtered.

Prop. It has not yet been obtained absolutely pure, more or less margarin and stearin always remaining. As above procured, it is a colorless, transparent fluid, of a sweetish taste and neutral to test paper. Is insoluble in water, but soluble in ether, the fat and essential oils, and also in 31 times its weight of boiling alcohol of spec. grav. .816. Crystallizes in needles at 19°, and, when heated, yields ACROLEIN, OLEIC, and other acids. The action of alkalies breaks up the original compound and forms new, which are termed SOAPS.

Oleic acid. Gottlieb's formula for the pure hydrated acid is $C_{36}H_{33}O_3 + HO$. It is prepared by the saponification of olein and direct from fats by the mode given in *Chem. Gaz.* iv. 357. The formulæ of Chevreul, Varrentrapp, and Bromeis are based upon analyses of the impure acid.

Prop. A limpid, colorless, oily liquid, tasteless, inodorous, and without action upon litmus paper. Melts at 57°, and solidifies at 40° into a white crystalline mass. In the liquid state it rapidly oxidizes. Is insoluble in water, but very soluble in alcohol and ether. Oleic acid, on exposure, becomes $C_{36}H_{33}O_5$, and with the aid of heat is transformed into $C_{34}H_{33}O_5$.

The oleic (linoleic) acid of drying oils, according to Sacc, is $C_{46}H_{38}O_5, HO$. It is more readily oxidized than that from fat oils, and resinifies on exposure. Though similar in physical properties to fat oleic acid, it differs from it in not crystallizing. Nitric acid converts it into a resinoid mass, which, by further oxidation, yields suberic, pimelic, oxalic, carbonic acids, and water.

Of the oleates, there are neutral, basic, and acid salts. The ready formation of the two latter prevents the preparations of the first without observance of the precaution given by Gottlieb. (*Ann. der Chem. und Pharm.*, lvii. 33.)

The alkaline oleates are soluble—those of the earths and metallic oxides are insoluble. The lead and baryta salts have the formula of RO, Ol. The alkaline oleates are decomposed into bi-salts, when treated with a large amount of water.

Action of heat upon Olein and Oleic acids. By distillation, oleic acid yields sebacic, CAPRIC, CAPRILIC, valerianic, BUTYRIC, carbonic acids, and carbo-hydrogens.

Sebacic acid. Formula $C_{10}H_8O_3$ (anhydrous) and $C_{10}H_8O_3 + HO$ (hydrated acid). The cha-

OLEIN.

racteristic product of the distillation of olein and oleic acid. It crystallizes in white pearly scales or needles, of a slightly acid taste, soluble in hot water, in alcohol, and ether. Fuses at 261° , and at a higher heat sublimes unaltered. The general formula of the sebates is RO, Sb. Of its salts, the alkaline are soluble and crystallizable. The ethyl sebate (AeO , Sb) is a colorless, oily liquid, of an agreeable odor. It is lighter than water, solidifies at 16° , and volatilizes above 212° .

Action of Nitric acid upon Olein and Oleic acids. When treated with nitrous acid, or nitrate of mercury, oleic acid solidifies into white crystalline elaidic acid.

Elaidic acid. Is isomeric with oleic acid. A small portion of this acid, when well-washed with water and added to a large quantity of oleic acid, acts as a leaven to convert the whole into elaidic acid. Is soluble in alcohol and ether, insoluble in water, fuses at 112° , and reddens litmus paper distinctly. Distils over for the most part unaltered. The alkaline elaidates are soluble and crystallizable. The elaidate of ethyl is an oily liquid. When olein is acted upon, the result is *elaidin* (elaidate of the oxide of glyceryl).

Nitric acid, in its reaction upon oleic acid, produces a series of acids. They are, besides the SUBERIC,—

1. *Azelaic acid.* $\text{C}_{10}\text{H}_8\text{O}_4$, HO. (Laurent.) Very soluble in ether.

2. *Pinelic acid.* $\text{C}_7\text{H}_5\text{O}_3$, HO (Laurent, Bromeis.) Also obtained from wax, stearic acid, spermaceti, and linseed oil. Crystallizes in pearly scales, soluble in hot water, ether, and alcohol, fusible at 238° , and distils unaltered. The baryta salt is 2 BaO , $\text{C}_7\text{H}_5\text{O}_3$.

3. *Adipic acid.* $\text{C}_{14}\text{H}_{10}\text{O}_7$, 2 HO. (Bromeis.) Results also from the oxidation of spermaceti and wax by nitric acid. Is very soluble in boiling water, and drops in needles which fuse at 266° , and may be distilled unaltered. The adipate of silver is 2 AgO , $\text{C}_{12}\text{H}_8\text{O}_6$, and the adipic ether $\text{C}_{12}\text{H}_8\text{O}_6$, $2 \text{ C}_4\text{H}_5\text{O}$. Malaguti.

4. *Lipic acid.* $\text{C}_5\text{H}_3\text{O}_4$, HO. (Laurent.) Crystallizes in plates, very soluble in cold water. Fuses at 285 to 295° , and sublimes unaltered. Distillation separates 2 eqivs. of water.

5. *Azoleic acid.* $\text{C}_{13}\text{H}_{13}\text{O}_4$.

Additional to the foregoing, Redtenbacher found among the volatile products of the oxidation of oleic acid by nitric acid, the following acids all belonging to the series $(\text{CH})_n + \text{O}_4$;—acetic, metacetic, butyric, valerianic, caproic, caprylic, cenanthylic, pelargonic, and capric acids.

Sulfoleic acid is produced by the action of oil of vitriol. Is soluble in water and alcohol, and forms soluble salts with the alkaline, and insoluble with the earthy bases. *Metoleic* and *(MOI, 2 HO) hydroleic* (HOI, 2 HO) are also products of the action of sulphuric acid.

Action of alkalis. The caustic alkalis at ordinary temperature convert olein and oleic acid into SOAPS; but when the latter are highly heated with 3 volumes of strong lye, salts of acetic, and a new acid are formed. Formula of this latter acid $\text{C}_{32}\text{H}_{30}\text{O}_3$, HO. It crystallizes from alcohol, and melts at 143° . Elaidin yields the same acid. Varrentrapp.

OLIVE OIL.

OLIBANUM. Chem. Syn. Frankincense.

The resinous gum of the *Boswellia thurifera*. It contains, according to Bracconnot,—

Volatile oil..... 8
Resin.....56
Gum.....30

Gummy matter, insoluble in water and alcohol..... 8-2

Volatile oil. Formula $\text{C}_{35}\text{H}_{28}\text{O}$. Stenhouse.

Resin. This, as found in the hard, rounded, brittle, white-dusted pieces, is acid, and has the composition $\text{C}_{40}\text{H}_{32}\text{O}_6$. In the long, clear, yellow tears it exists as $\text{C}_{40}\text{H}_{22}\text{O}_4$. Johnston.

OLIGISTE IRON. See SPECULAR IRON.

OLIGOCLASE. Min. Sodaspodumen, red albite, aventurine feldspar. Cryst. Triclinic, with one distinct and two less perfect cleavages. H. = 6. G. = 2.63—2.67. Color white, yellowish or greenish; vitreous or brightest cleavage surface, otherwise greasy; transparent, subtranslucent; fracture conchoidal, uneven. It behaves like feldspar, but fuses more readily to a colorless glass. Form. NaO , $\text{SiO}_3 + \text{Al}_2\text{O}_3$, 2 SiO_3 , in which NaO includes a portion of KO, CaO, MgO. It differs from feldspar in containing 1 equiv. less of SiO. A lime oligoclase, analyzed by Forchhammer and Swanberg, spec. grav. = 2.729—2.69, has the form. CaO (NaO) $\text{SiO}_3 + 3 (\text{Al}_2\text{O}_3, 2 \text{ SiO}_3)$.

Local. Arendal; Schaitansk; Catherinenburg; Kimits, Finland; Silesia; Hartz; aventurine feldspar from Toedestrand, Norway; lime oligoclase from Hafnefjord, Iceland.

OLIGON SPAR. See SPARRY IRON.

OLIVINE. See CHRYSOLITE. Scacchi's examination of a light yellow olivine, gives the formula 3 CaO, $\text{SiO}_3 + 3 \text{ MgO}$, SiO_3 . It is softer than usual, and more easily decomposed by acids.

OLIVENITE. Min. Cryst. Right rhombic; also fibrous, curved-lamellar, granular. H. = 3. G. = 3.913—4.28. Various shades of olive-green, also brown; adamantine, vitreous; subtransparent, opaque; brittle. Yields water in a tube; fuses on coal with detonation, and evolving arsenical vapors to a white brittle regulus; fused in the pincette it crystallizes on cooling. Soluble in nitric acid and in ammonia, and decomposed by potassa. Form. 4 CuO, $\text{AsO}_5 + \text{HO}$, or rather 3 CuO, $\text{AsO}_5 + \text{CuO}$, HO, in which part of the AsO_5 is replaced by PO_5 . From Cornwall. See ARSENIOPHOSPHATES.

OLIVE OIL. Syn. Gallipoli oil, Florence oil, Lucca oil. Obtained by pressure from the fruit of the *Olea Europea*. When well made, it is of a yellowish color, but some lots have a greenish tinge, transparent, insoluble in water, slightly soluble in alcohol and ether.

There are three commercial kinds of olive oil. The best called "virgin salad oil" is extracted from the fruit by gentle pressure in the cold; the next grade is procured by a stronger pressure, aided by the heat of boiling water; and a quality of still greater inferiority by boiling the residuum or *marc* of the olives (after the two first pressures) with water, and collecting the oleo-mucilaginous layer which rises to the surface.

Prop. It consists of 72 parts of olein and 28 parts of margarin. At 32° to 22° it deposits nearly all its solid constituent. When to

be used for lubricating the working joints of delicate machinery, it must be thoroughly purified by agitation with a solution of subacetate of lead, treating the clarified oil with dilute sulphuric acid, washing the mixture with boiling water and leaving the oil over melted chloride of calcium.

Uses and Adulteration. The pure salad oil is used for table and domestic purposes, the inferior kinds in the manufacture of soaps. Its superiority over other sorts of oil, and higher price, render it liable to adulteration, more especially with lard oil, which sometimes forms as high as sixty or seventy per cent. of "*surfin Lucca huile*." To guard against such impositions, we give below a means of detecting them. The lard oil always contains more or less of stearin, which it drops at a much higher temperature than that at which the margarin falls from the olive oil. This behavior allows an approximately correct judgment. To verify it, the solid deposit must be separated by filtration, saponified, the resulting soap decomposed, and the eliminated acid carefully dried. The point of fusion then carefully ascertained will determine whether it is stearic or margaric acid; if the former, then it is proper to infer the presence of lard oil.

Oil of poppies, too, is not an unfrequent falsification of olive oil; it is detected by the addition of hyponitric (nitrous) acid to the latter, which, if pure, becomes solid, or, more properly speaking, transformed into elaidin, whilst if there is but $\frac{1}{10}$ th of poppy oil present, the concretion is prevented, a greasy paste only being produced. The composition of olive oil is oleic and margaric acids in union with glycerin; the more solid constituent, or margarate of glycerin, being in the proportion of about twenty to twenty-eight per cent.

The bad conducting power of olive oil (being 675 times worse than other vegetable oils) induced Rousseau to use the *electrical diagnetometer* as a means of testing its purity. This apparatus consists of one of Zamboni's dry piles and a feebly magnetized needle, moving freely on a pivot. The electricity developed by the pile produces a deviation in the direction of the needle; but when any substance is interposed between the needle and the pile, the deviation is less in proportion to the bad conducting power of the interposed substance. The addition of two drops of poppy or beech nut oil to 154.5 grains of olive oil is sufficient to quadruple the conducting power of the latter.

Freezing is also sometimes used to test the presence of poppy oil, which prevents perfect congelation when in the proportion of only 1 to 2.

OLIVILE. *Chem.* Olivile, which was discovered and analyzed by M. Pelletier, in 1816, is very easily obtained by first submitting the pulverized resin of the olive to treatment with ether; then dissolving the residue in boiling alcohol, and leaving the filtered solution to crystallize on cooling. It is easily freed from the resinous matter with which it is impurified, by throwing it on a filter and washing it with cold alcohol, which dissolves but very little of it, and leaves it perfectly white. By redissolving and crystallizing it anew, it is obtained in small brilliant radiated needles.

Olivile dissolves readily in alcohol and in

water, and crystallizes from both mediums. It also dissolves in ether, but in very small quantity, and in volatile and fixed oils.

Olivile, like lithofellinic acid, silvic acid, and other substances, exhibits the phenomenon of a different melting point in its crystalline and amorphous state. When in crystals its point of fusion is at 248° Fahr.; on melting it acquires a resinous aspect, and neither increases nor decreases in weight; it does not lose its transparency on cooling; it fractures, without however again assuming its crystalline structure; in this state its melting point is 158°. By dissolving it in alcohol, and crystallizing it afresh, its melting point again becomes 248° Fahr.

Olivile may be obtained anhydrous, monohydrated or bihydrated. Anhydrous olivile is obtained by causing it to crystallize in anhydrous alcohol, or by melting crystallized olivile in water. Its composition leads to the formula $C_{14}H_9O_5$.

Olivile, crystallized in water, and dried in the vacuum of the air-pump over sulphuric acid until it loses no more in weight, retains 1 equiv. of water, of which it can only be deprived by fusion.

Olivile combines with oxide of lead, and affords a salt, the composition of which represents 1 equiv. of anhydrous olivile and 2 equivs. of oxide of lead. (*Journ. de Pharm.* for April, 1843.)

OLIVINE. Syn. Olivite. Landerer obtained it by heating the leaves of the olive tree with acidulated water, concentrating the extract, and supersaturating it with ammonia. The greenish yellow precipitate thrown down is purified by solution in hydrochloric acid, filtration through charcoal, and reprecipitation by an alkali. This precipitate crystallizes from alcohol in colorless crystals, which are bitter, insoluble in water and soluble in acids without forming crystallizable compounds. In burning, it emits aromatic vapors.

ONEGITE. See BROWN HEMATITE.

OMICHYL. See URINE.

OMPHAZITE. See AUGITE.

ONYX. See QUARTZ.

OOLITE. See varieties of CALCAREOUS SPAR.

ONION. The bulb of the *Allium cepa* contains, according to Fourcroy and Vauquelin, an acid volatile oil, uncrySTALLIZABLE sugar, gum, woody fibre, albumen, acetic, and phosphoric acids, phosphate and citrate of lime and water. The piquant odor of onion juice is due to the volatile oil, which is colorless and acrid, and like that of garlic, to which it is probably otherwise analogous, contains sulphur.

OPAL. *Min.* Amorphous. H. = 5.5—6.5. G. = 2—2.21. White, yellow, red, green, gray, brown; vitreous, sometimes resinous and pearly. The *precious opal* exhibits a beautiful play of colors; *fire opal* or *girasol* is subtransparent, translucent, bright wine-red, yellow, and slightly milky. The play of colors is destroyed by heat. Most varieties decrepitate by rapid heat, yield water in a tube, and otherwise behave like quartz, except that opal is mostly soluble in caustic potassa. Opal is essentially silica, probably deposited from thermal waters and hot aqueous vapors, resembling gelatinous silica, obtained by dissolving some silicates.

But it would seem as if there were a definite hydrate, $3\text{SiO}_2 + \text{HO}$, and that other opals are mixtures of this hydrate with silica and very acid silicates.

Besides the precious and fire opal, other varieties are *common opal* and *semiopal*, less pure than the preceding; *hydrophane*, becoming transparent by immersion in water; *cacholong*, milky and opaque; *hyalite* or *Muller's glass*, in small botryoidal shapes, found in the United States at Phillips' ore-bed, Putnam Co., N. Y., and in the Georgia bularstone; *menilite*, brown and opaque; *alumo-calcite*, bluish, milky; *michaelite*, fibrous, pearly; *pearl sinter*, smooth, globular masses in volcanic tufa; *silicious sinter*, porous, fibrous, compact deposits from the Geysers of Iceland; *wood opal*, with a ligneous structure.

OPHITE. See SERPENTINE.

OPIUM. *Chem. Pharm.* The juice of the *Papaver somniferum*, which exudes from incisions made into the poppy heads. There are several varieties of opium, of which the principal are:—

Turkey opium. That which comes from Smyrna is in irregular, soft lumps, covered on the surface with the reddish capsules of some species of *Rumex*. The color in the interior is reddish brown, but darkens on exposure. This, the best quality, contains from 6 to 9 pr. ct. of morphia.

The Constantinople species comes in regular flattened cakes, covered with a poppy leaf, the medium nerves of which divide the disk into two parts. It is drier than that from Smyrna, and is sometimes even hard; but softens by kneading, giving a light part which browns in the air. Its content of morphia is 5 to 6 pr. ct.

Egyptian or Alexandrian opium. Is found in commerce as small flattened cakes, with smooth surfaces. Its color is brown, and, being hard, it breaks readily and emits a feeble odor. It contains but 3 to 4 pr. ct. of morphia.

Indian opium. Of this there are two varieties, that from Benares and the other from Bengal. They contain from $2\frac{1}{2}$ to 4 pr. ct. of morphia.

The composition of opium is very nearly the same in each variety, though the amount of the several constituents vary essentially. MORPHIA and CODEIN are the active principles, but it contains also NARCOTIN, narcein, MECONIN, meconic acid, thebaine or paramorphia, papaverin, pseudomorphia, porphyroxin, a brown extractive acid, resin, fat and volatile oil, bassorin, gum-caoutchouc, lignin, and salts.

The quality of the opium, even from the same locality, often differs, and this is owing to the state of the atmosphere during the harvest, damp or wet weather greatly impairing its value. The usual adulterations, with which it is not unfrequently contaminated, are Armenian bole, grape skins, poppy stalks, and the epidermis of the capsule, stone, gravel, sand, and earthy matters. Opium which has been exhausted of its morphine is also sometimes worked into cakes and sent into the market.

Narcein. $\text{C}_{28}\text{H}_{20}\text{NO}_{12}$? (*Couerbe.*) Crystallizes in colorless, silky needles, of a bitter metallic taste. Melts at 198° , but decomposes at a higher heat, dissolves readily in alcohol and sparingly in water, and is insoluble in

ether. Is neutral, and drops in crystals unaltered from its solution in acids. Strong HCl acid colors it azure blue, and the liquid, on evaporation, passes successively from red to violet, and ultimately to deep blue. Hygroscopic substances, such as chloride of calcium, produce a similar reaction.

Thebaine. Syn. Paramorphia. $\text{C}_{25}\text{H}_{14}\text{NO}_3$. (*Kane.*) Crystallizes in colorless grains or needles, of a sharp, metallic taste and alkaline reaction. Fuses at 300° , but decomposes at a higher temperature. Dissolves in alcohol and ether, but is insoluble in water. Its salts are crystallizable.

Papaverin. $\text{C}_{40}\text{H}_{21}\text{NO}_3$. (*Merck.*) Forms white acicular needles, slightly soluble in cold, more soluble in boiling alcohol. It is insoluble in water, and ether takes it up but sparingly. Strong sulphuric acid turns the crystals blue.

Its salts are very sparingly soluble in water, and the muriate crystallizes in right rhombic prisms. (*Liebig's Annalen*, April, 1848.)

Pseudo-morphia. $\text{C}_{27}\text{H}_{18}\text{NO}_{24}$ (?) (*Pelletier.*) Crystallizes in brilliant plates, slightly soluble in water and dilute alcohol, but insoluble in absolute alcohol and ether.

Porphyroxin. Forms brilliant needles, soluble in alcohol and ether, but insoluble in water. Is neutral, and when treated with HCl acid, gives a purple solution.

OPOBALSAM. *Pharm.* Syn. Balm of Gilead, Mecca balsam. A whitish, turbid liquid, flowing from incisions made in the *Balsamodendron Opobalsamum*, or Beshan of Arabia. It is very odorous, and on exposure resinifies. It consists of 30 pr. ct. volatile oil, and 70 pr. ct. resin and extractive matter.

OPOPONAX. *Chem.* The milky juice of the root of the *Opoponax chironium*, which exudes from incisions, and on drying becomes a yellow gum resin. It contains volatile oil, and its resin, according to Johnston, has the formula $\text{C}_{40}\text{H}_{25}\text{O}_{14}$. The latter is fusible at 122° , and soluble in alcohol, ether, and the alkalies. The acids precipitate it from its alkaline solutions in yellow flocks.

ORANGES, OIL OF. *Chem. Syn. Ess.* of Portugal. The distilled essence of the *Citrus aurantium*, varying in title, odor, and property with the part of the plant whence extracted. Thus the peel yields the oil proper: the flowers give the essence of *neroli*. The oil obtained from the *orange-berries*, as they are termed, or from the leaves of the *Citrus bigarea*, is called essence of *petit-grain*.

Portugal. Spec. grav. 0.835; boiling point, 356° . With HCl acid it forms a compound analogous to that from oil of lemons.

Neroli. Nearly colorless when fresh, but reddens on exposure. According to Souberain and Capitaine, it consists of two oils:—one of a very grateful odor and soluble in water, the other nearly insoluble. The first is reddened by sulphuric acid. Boullay and Plisson, by means of alcohol, separated a stearopten, insoluble in water, but very soluble in ether. According to Dobereiner, this essence yields, in contact with platina black, a peculiar acid,

HESPEREDIN. Obtained from the spongy part of the orange and lemon peel. Crystallizes in groups of needles, is white, tasteless, inodorous, and decomposes by heat without evolution

of ammonia. Is insoluble in cold water and in ether, slightly soluble in boiling water, and very soluble in alcohol and acetic acid.

ORCHIL. See LITMUS in LICHENS.

ORCIN. See LICHENS.

ORMOLU. An alloy of 52 parts of zinc and 48 of copper, much used in the manufacture of the ornamental parts of lamps, chandeliers, &c.

OROSELON. *Chem.* Formula $C_{14}H_5O_3$. A body acting the part of a base (replacing glycerin) in *athamantin*. (*Chem. Gaz.* iii.) A substance, analogous in composition to fats, obtained from the *Athamanta ore oselinum*.

Prep. When dry muriatic gas is passed over *athamantin* at the ordinary temperature, it transforms it into a yellowish brown liquid, which subsequently solidifies into groups of acicular crystals. By the distillation of these crystals, hydrated valerician acid is generated and passes over as a clear, colorless liquid, while the mass becomes thick and gradually opaque from the separation of a solid body. This mass, as soon as it is quite stiff and dry, is oroselon, of a grayish white color. Crystallization from its solution in alcohol (which dissolves it with difficulty) yields it in purified acicular crystals aggregated in warty groups.

Prop. It is tasteless and inodorous, insoluble in water, and as soluble in ether as in alcohol, with a yellow color. In strong potassa solution, with the aid of heat, it partially dissolves with a reddish brown color, but is thrown down again by the acid as a yellowish white precipitate. It melts at 374° into a clear, yellow fluid, which solidifies on cooling into a crystalline mass, which at a higher heat is destroyed. According to theory, 100 parts *athamantin* should yield 52.7 parts oroselon, but Winckler and Schnedderman, the chemists who determined the aforementioned results, obtained 56.2 per cent.

ORPIMENT. *Min. Lat.* Auripigmentum. *Ger.* Operment, Rauschgelb. Cryst. Right rhombic, cleaving perfectly parallel to a lateral end-plane. $H. = 1.5 - 2$. $G. = 3.48$. Yellow; lustre submetallic, pearly on cleavage faces, otherwise resinous; subtransparent, translucent; sectile, with gold-yellow streak; thin laminae flexible, not elastic. Sublimes in a closed tube to a dark yellow or red fluid, which congeals; in an open tube it yields sulphurous and arsenious acids; soluble in aqua regia, potassa, and ammonia. Form. AsS_3 . From metalliferous veins in Hungary.

ORPIMENT. See ARSENIC.

ORSELLIC ACID. See LICHENS.

ORTHITE. *Min.* Is closely allied to ALANITE. Scheerer unites allanite, cerine, and orthite under one and the same general formula, $3(R_2O, SiO_3) + 2(R_2O_3, SiO_3)$, in which $RO = CeO, LnO, FeO, MnO, MgO, CaO, YO$, and perhaps GO ; $R_2O_3 = Al_2O_3, Fe_2O_3$.

OSMAZONE. The extractive matters of flesh which impart to cooked meat its savor. See p. 110, ALIMENTARY PRINCIPLES.

OSMIUM. *Chem.* A grayish metal discovered by Tennant in 1803. When precipitated from its solutions by organic matters it is often bluish. Exists native in PLATINUM sand, to which article refer for the process of extraction.

Prop. Sym. Os — Eq. 100 ($H. = 1$). Spec. grav. 10. Neither volatile nor fusible. Absorbs

oxygen by exposure, and burns when heated in the air, and becomes osmic acid. Nitric acid dissolves it, forming osmic acid. It is also transformed into osmiate by ignition with alkalis and nitre. It combines with oxygen in several proportions, as follows:—

1. *Protoxide.* OsO . Obtained by precipitating the double proto-chloride of osmium and potassium with potassa. A dark-green powder, which retains a little potassa, difficultly separable by water. When heated, water is given off, but no oxygen or volatile acid; if air is admitted, it oxidizes and sublimes. Is reduced by hydrogen. Unites with acids and forms green salts.

2. *Sesquioxide.* Os_2O_3 . Obtained only in union with ammonia by long heating of a mixture of osmic acid and ammonia at 100° to 120° . Nitrogen is eliminated and black sesquioxide remains. When heated, it becomes luminous and reduced to metal. By boiling with potassa it becomes fulminating. Dissolves with difficulty in acids, forming yellowish brown, uncrystallizable compounds.

3. *Binoxide.* OsO_2 . Obtained by the action of carbonated alkalis upon the double bichloride of osmium and potassium. Brownish black. Heated in close vessels without alteration, but oxidizes upon the admission of air. Detonates when heated with combustibles. Is easily reduced by hydrogen. Insoluble in acids except in its nascent state.

4. *Osmious acid.* OsO_3 . Known only in combination with bases. The osmite of potassa, $KO, OsO_3, 2HO$, may be prepared by deutoxide of osmium in osmiate of potassa, or by adding alcohol to the osmiate of potassa which is thus deoxidized. This salt is red, soluble in water, insoluble in alcohol and ether, unalterable in dry air, but changed by moist air and by acids.

5. *Osmic acid.* OsO_4 . Prepared by heating osmium in air or in oxygen, or with nitric acid, or by decomposing an osmiate or an osmite with an acid. Crystallizes in long colorless prisms. Has a pungent odor of horseradish, and is very poisonous. Melts below 212° , and volatilizes at that temperature. Is soluble in water, alcohol, and ether. The latter two, however, ultimately reduce it. Does not unite with acids, but forms feeble salts with the bases, of a yellow or orange color.

Osman-osmic acid. $OsN + OsO_4$. (*Fritzsche and Struve.*) A combination of the nituret of osmium with osmic acid. Forms crystalline salts, which are more or less soluble in water, and detonate when heated. The free acid may be obtained by decomposing the baryta salt with sulphuric acid. It decomposes carbonates with effervescence. The potassa salt ($KO, OsO_4 + OsN$) forms yellow crystals partially soluble in water, and still less so in alcohol.

The baryta salt crystallizes in yellow needles, soluble in water.

The zinc salt is very soluble and uncrystallizable.

SULPHUR. There are several compounds with sulphur—the monosulphuret OsS ; the sesquisulphuret Os_2O_3 , the bisulphuret OsS_3 , and the osmic sulphuret OsS_4 .

CHLORINE. There are four chlorides corres-

ponding with four oxides, and which combine to form double salts. Their formulæ are OsCl , Os_2Cl_3 , OsCl_2 , OsCl_3 .

SALTS. The *sulphate*, OsO , SO_3 , is grayish brown. The *nitrate*, OsO , NO_5 , forms a green translucent varnish. Of the osmic salts, only the sulphate is known. It is deep-brownish yellow, and of syrupy consistence, and soluble in water.

OSMIUM-IRIDIUM. See IRIDOSMIN.

OSTREOCOLLA. See CALCAREOUS SPAR.

OTTO OF ROSES. See ROSES.

OTTRELITE. *Min.* In small brilliant plates. $H. = 6(?)$ $G. = 4.4$. Grayish or greenish black, with pale green streak and uneven fracture. Yields water in a tube; fuses with difficulty on the edges to a black magnetic bead; slowly soluble in borax, giving the reaction of iron, and showing the presence of manganese with soda. Form. 3FeO , $2 \text{SiO}_3 + 2 (\text{Al}_2\text{O}_3, \text{SiO}_3) + 3 \text{HO}$. From Ottrez, Luxemburg.

OUVAROVITE. See GARNET.

OXALATE OF LIME. *Min.* Cryst. Oblique rhombic. $H. = 2.5$. $G. = 2.75$. Very brittle, with conchoidal fracture. Locality unknown.

OXALIC ACID. *Chem. Tech.* This acid exists as binoxalate of potassa in the juice of certain plants, as the genera *Rumex* and *Oxalis*. It is also found in several minerals and urinary calculi. It may be formed artificially by the action of nitric acid upon organic compounds free from nitrogen. It is used in calico printing as a bleaching and discharge agent.

Prep. 1. Digest 1 pt. of sugar dried at 212° with 8.25 pts. nitric acid of 1.38 spec. grav. Evaporate the mixture to a sixth, and leave to crystallize. These proportions have been shown by Bemiger to be the best, as the process yields 50 to 60 pr. ct. of handsome crystals of acid, and requires but an hour or two for its completion.

2. Add 144 parts of nitric acid (made by mixing the acid of commerce with 10 parts of water) very gradually and portionwise to 24 parts of starch, and after the reaction ceases apply gentle heat. When nitrous vapors cease, set aside to crystallize. This process (*Robiquet's*) yields 12 parts of acid. The mother waters yield more, upon further treatment with fresh quantities of nitric acid.

Prop. Forms oblique quadrilateral, colorless, transparent prisms, with two-sided summits, of composition C_2H_3 , 3 HO and spec. grav. 1.507. At 212° , and even by exposure to dry air at 105° to 125° , they lose 2 equivs. HO without being altered. A higher heat produces decomposition, carbonic oxide and acid and formic acid being evolved.

These crystals are inodorous, but have a strongly acid taste. Are soluble in water and in 4 parts of alcohol. Oxalic acid is highly poisonous, and lime and magnesia is the antidote, with either of which it forms an insoluble compound. For the bases it has a strong affinity, and unites with them to form an extensive class of neutral and acid salts. When pure, it should completely volatilize upon being heated, and give no precipitate with chloride of barium, insoluble in NO_5 . Sometimes it may contain nitric and tartaric acids; the presence of the former is detected in the usual

manner. If it contains tartaric acid it will become black when digested with sulphuric acid.

Oxalates. Excepting the alkaline, nearly all the oxalates are insoluble in water. Many of these, with metallic oxides as bases, are easily reduced to metal by heat, carbonic acid being evolved. So also many oxides, when heated with an oxalate, are reduced by the carbonic acid generated. The alkaline oxalates become carbonates when heated.

Oxalic forms both neutral and acid salts. Those with base R_2O_3 are sufficiently soluble. Those of soda, silver, and lead are anhydrous; the others contain 1, 2, or 3 equivs. of water. The alkalies form acid oxalates. The double oxalates are chiefly an alkaline oxalate, with one containing R_2O_3 .

Oxalic ether. The neutral oxalate of ethyl is a colorless, transparent, aromatic, oily fluid, of spec. grav. 1.0929 at 46° . Its composition is AeO , Ox . Boils at 370° , mixes with alcohol and ether, and is sparingly soluble in water. It is, when not perfectly pure, prone to decomposition. When its alcoholic solution is neutralized, to the extent of one-half of its content of oxalic acid, with potassa dissolved in alcohol, a double salt is formed, containing 2 equivs. oxalic acid, 1 equiv. of ethyl, and 1 equiv. of potassa.

Binoxalate of oxide of ethyl. Syn. Oxalovinic acid. Formula AeO , $\text{Ox} + \text{HO}$, Ox . A very sour liquid, which readily changes into oxalic acid and alcohol. The *oxalovinate of potassa* (AeO , $\text{Ox} + \text{KO}$, Ox) forms anhydrous, crystalline scales, perfectly soluble in alcohol of 75 pr. ct., decomposable by acids and alkalies, and remaining unaltered up to 212° . The baryta salt is very soluble in water, but is of difficult crystallization. Oxalic ether, when treated with an excess of ammonia in presence of water, yields *oxamide*. (*Bunhof.*) By substituting alcohol for the water and lessening the quantity of ammonia, *oxamethane* is formed. *Dumas and Balard.*

Oxamide. A white, crystalline, tasteless, inodorous powder, $(\text{NH}_2 + \text{C}_2\text{O}_2)$, slightly soluble in boiling water, but nearly insoluble in cold water, alcohol, and ether.

Oxamethane. Syn. Oxamate of oxide of ethyl. Oxalate of oxide of ethyl and oxamide. Forms colorless, transparent scales of composition, $\text{C}_8\text{H}_7\text{NO}_6$. Is soluble in water and alcohol, melts at 212° and distils unaltered at 430° . It is neutral, and does not precipitate metallic salts.

OXALITE. *Min.* Oxalate of iron, Humboldt, Eiscuresin. Yellow, earthy, soft. $G. = 2.13 - 2.49$. Blackens in candle-flame, and becomes magnetic; on charcoal it becomes black, then red, and with the fluxes gives the reaction of iron; soluble in acids, decomposed by alkalies, with separation of green hydrate of iron which browns in the air. Form. $2 (\text{FeO}, \text{C}_2\text{O}_3) + 3 \text{HO}$.

OXALOVINIC ACID. See OXALIC ACID.

OXALURIC ACID. See URINE.

OXAMIDE. See OXALIC ACID.

OXHAVERITE. See APROPHYLITE.

OXIDATION. } *Chem.* When a body unites
OXIDES. } with oxygen, oxidation takes

place, and if the resulting compound consist only of a radical and oxygen, it is termed an oxide. As some bodies have the property of uniting with oxygen in several proportions, the degree of oxidation is designated by the prefixes *sub*, *proto*, *sesqui*, *bi*, *ter*, and *per*, accordingly as the oxygen is in a ratio to the radical of $\frac{1}{2}$ to 1, 1 to 1, $1\frac{1}{2}$ to 1 or 3 to 2, 2 to 1, 3 to 1, or higher. Sometimes, as in the case of several metals, the oxides have acid properties, and then take the name of acids, as tantalic, niobic, and arsenic acids.

OXYCHLORIDES. *Chem.* Those compounds which consist of chloride and oxide of the same metal. In some few instances the chloride is of some other metal.

OXYGEN. *Chem. Ger.* Sauerstoff. *Fr.* Eau. *Syn.* Dephlogisticated and Vital air, Empyreal air. A gaseous body, discovered by Priestley in 1774, and taking its name from two Greek words *ἔξω*, *acid*, and *γεννάω*, *I produce*, because it was at first thought to be the sole acidifying principle. Modern discoveries soon rectified this error, by proving the existence of acids, in the composition of which there is no oxygen. A similar mistake, assigning to it exclusively the property of supporting combustion, has also, in like manner, been corrected. Oxygen possesses the above properties, however, in a more eminent degree than any other body. It is found largely diffused throughout all nature, being an important element of AIR and WATER, rocks, earths, minerals, and organic matters, the proportion of substances free from it being very limited. *Sym.* O. *Eq.* 100 when H = 12.50, or 8 when H = 1.

Prop. 1. By heating chlorate of potassa (KO, ClO_3) in a glass retort, which gives off all its oxygen, and becomes KCl. A portion of peroxide of manganese or of oxide of copper facilitates the reaction. 2. By distilling the red oxide of mercury in an earthen retort: oxygen is eliminated, and metallic mercury passes over. 3. By decomposing the peroxide of manganese at a high heat in an iron flask. By this process the peroxide loses one-third of its oxygen, and becomes brown oxide of manganese. 4. By carefully heating nitrate of potassa. 5. From a mixture of chloride of lime and peroxide of manganese. (*Lond. Pharm. Journ.* vii. 399.) The gas generated by either of these processes may be collected in the pneumatic trough in bell glasses, for immediate experiment, and in small quantities; but in larger proportions, as stock for gradual use, it is better to collect and preserve it in gasometers, of which Pepy's is the most convenient.

Prop. A permanent, elastic, transparent, colorless, tasteless, inodorous gas, of spec. grav. 1.105. Is very slightly soluble in water. Is a powerful supporter of combustion and respiration, and refracts light less than any other known body. Sulphur, charcoal, phosphorus, and all substances combustible in air, burn with increased brilliancy in oxygen gas. Indeed, many substances not combustible in the air, when previously heated, for example many of the metals, are rapidly burned in this gas. The resultant products are new compounds, in which the absorbed oxygen forms a part.

It combines with other elements to form

(electro-positive) oxides or (electro-negative) acids, accordingly as the newly-formed body is acid or basic in its properties. When it unites in more than one proportion with a body, the degree of oxidation is designated by certain prefixes, as *sub*, *proto*, *deuto*, *per*, and *super*, in reference to bases, or by *hypo*, *hyper*, or the termination *ous* or *ic*, in reference to acids. Most of the oxides act the part of a salifiable base, but there are some exceptions, which give rise to the appellation of neutral or indifferent oxides. The affinity of bodies for oxygen varies, and serves as one of their characteristics.

A mixture of oxygen and HYDROGEN, when ignited, produces an intense heat, and constitutes the Hydrogen BLOWPIPE, invented by Dr. Hare. When this ignited flame is projected against lime, the latter becomes intensely luminous, and forms the well-known DRUMMOND LIGHT.

OXYHYDROGEN BLOWPIPE. See BLOWPIPE.

OXYMURIATES. *Chem.* Compounds of bases with chloric acid. See CHLORINE.

OZOKERITE. *Min.* Erdwachs. Waxy and resinous-like. *G.* = 0.946—0.953. Brown, brownish yellow by transmitted, green by reflected light; odor feebly bituminous. Fuses at 143° to 183° in the flame of a candle to a clear, oily liquid, which congeals on cooling; boils at 410° — 570° ; at a higher heat burns with flame, and is almost wholly volatilized. According to Johnston it fuses at 140° , and begins to boil at 260° , when first a colorless, then a dark distillate passes over. Not attacked by strong acids, slightly soluble in alcohol; cold ether dissolves $\frac{1}{4}$, and from the remainder boiling alcohol or ether extracts a small quantity, which they leave colorless upon evaporation. The formula of the whole and of that soluble in ether is CH. See HATCHETIN.

OZONE. *Chem.* The peculiar matter constituting the odor produced in oxygen gas and in the air by the electric spark evolved on the discharge of an electric battery. Hence its name from the Greek word, *ἴζω*, *to yield odor*.

Marignac obtained it readily by slowly passing a current of moist air through a tube of 1 metre in length and 6 millimetres in diameter, containing pieces of phosphorus. The phosphorus exerts only a catalytic action. Perfectly dry air will not yield ozone.

Comp. Schönbein, the discoverer, first suggested that it was a new element, but subsequently announced it to be a superoxide of hydrogen, formed either under catalytic influences, or in the establishment of the electrical equilibrium in the air, when a portion of the atmospheric oxygen combines with aqueous vapor. Williamson (*Chem. Gaz.* iii. 358) and Marignac (*Comptes Rendus*, 1845), on the contrary, regard it as oxygen in a different allotropic condition from ordinary oxygen gas; and in this view they are supported by the opinions of Berzelius and Larive. Recently, however, Bunsen has examined the subject, and confirms Schönbein's conjecture, that it is a higher oxide of hydrogen than water, and shows its composition to be either HO_4 or HO_5 .

Prop. Ozone is eminently oxidizing, and when inhaled produces irritation of the mucous membrane of the respiratory organs. It

is absorbed by a solution of iodide of potassium, which gradually decomposes, becoming yellow, and ultimately colorless. As the separation of iodine is not effected by nitrogen, oxygen, or a mixture of atmospheric air and carbonic acid, this reaction serves, when a solution of starch incorporated with iodide of potassium is present, to detect the minutest quantity of ozone in any amount of air, the resulting blue color having an intensity proportionate to the quantity of ozone present. Ozone is also absorbed by certain finely-divided metals, but without oxidizing them or losing its odor, provided every trace of moisture has been previously removed from the gaseous mixture. Water, strong sulphuric acid, caustic ammonia, baryta water, or chloride of calcium do not absorb it. Ozone decomposes indigo, and even bromide of potassium. In presence of water it converts iodine into iodic acid, protoxide into peroxide of iron, and sulphuretted hydrogen into oxide of lead.

Sulphuretted hydrogen and sulphurous acid immediately decompose it, and hence, in the vicinity of cesspools, or wherever these emanations are given off, the iodo-salt starch-paste is not colored blue. Schönbein has remarked, after numerous experiments, that the rapidity with which the mixture of starch-paste and iodide of potassium is turned blue by ozonized air varies at different times: a deeper color ensuing at one period in a few hours than at another in as many days. In the colder seasons, during a fall of snow, or in the summer, during thunder storms, the blue color is produced of greater depth and with more rapidity. As electrical discharges are of continual occurrence in the atmosphere, ozone is always present; but the quantity augments with the intensity of the charges, and with the diminution of the atmospheric temperature. Hence it follows, especially when there are but few organic, oxidable, or other matters upon or near to the earth's surface capable of decomposing or absorbing it, that an accumulation takes place. To this excess of ozone as affecting the normal condition of the atmosphere, certain epidemics, particularly those of a catarrhal character, have been attributed. With what truth such an hypothesis may be supported, remains to be determined by further investigations.

P.

PACKFONG. See ARGENTAN.

PAGODITE. See AGALMATOLITE.

PALAGONITE. *Geol.* The characteristic Plutonic rock of the first period of upheaval in Iceland. H. = 5. G. = 2.43. Amorphous, brown, waxy, translucent. Form. $3\text{RO}, 2\text{SiO}_3 + 2(\text{R}_2\text{O}_3, \text{SiO}_3) + 9\text{HO}$, in which $\text{RO} = \text{CaO}, \text{MgO}, \text{KO}, \text{NaO}$, and $\text{R}_2\text{O}_3 + \text{Fe}_2\text{O}_3, \text{Al}_2\text{O}_3$. It bears a close relation, in composition, to OTTRELITE and SCAPOLITE. *Bunsen.*

PALLADIUM. *Min.* In grains with diverging fibres. H. = 5. G. = 12. Metallic, between silver and steel; ductile and malleable. With the platinum sand of Brazil.

PALLADIUM. *Chem.* A grayish white, rare metal, discovered by Wollaston in 1803. It exists in native platinum, constituting about

1 pr. ct. of the Columbian, and $\frac{1}{4}$ to 1 pr. ct. of the Uralian ores of this metal. Also accompanies Brazilian gold, and is found combined with selenium in the Hartz, near Tilkerode.

Prep. Dissolve platinum sand in *aqua regia*, expel the excess of acid by evaporation, and then add solution of cyanide of mercury until precipitation ceases. The palladium alone is thrown down, the mercurial salt not being decomposed by any of the other metals present. The precipitate is bright yellow, and when heated to redness becomes pure palladium. See PLATINUM.

Prop. Sym. Pd. Eq. 53.3 (H. = 1), or 665.9 (O. = 100). Spec. grav. 11.3 in the melted state, —11.8 when hammered; spec. heat 0.05927. Difficultly fusible, ductile, and very malleable. Oxidable only at high temperatures.

Fischer (*Poggendorff's Annalen*, lxxi. p. 431) reports its behavior to acids and alkalis as follows:—Cold nitric acid dissolves it slowly without evolution of gas, but when heated the action is rapid, and nitrous oxide disengages. Sulphuric acid dissolves the filings, but not the welded metal, with the disengagement of sulphurous acid. The solution is not rendered turbid by dilution with water. The better way, however, of making the protosulphate, is by the use of nitric and sulphuric acids, as recommended by Kane. Hydrochloric acid acts slightly upon the welded metal, but dissolves it readily in the state of filings or when porous, that is, as obtained by igniting some of its salts. The better plan, however, of preparing the chloride, is to pass chlorine into the metal until solution is complete. The other acids are without action upon metallic palladium.

Salts. Potash and soda precipitate from neutral solutions of the protonitrate of palladium a basic salt, which is insoluble in an excess of the precipitant, and is converted on boiling with it into hydrated protoxide. Carbonate of potash and soda produce, neither in acid nor in neutral solutions of the protoxide, any precipitate, and no carbonic acid is disengaged on their addition to neutral solutions; the liquid merely assumes a darker color. On boiling this liquid, basic protocarbonate of palladium subsides; the supernatant liquid has a light brown color, but contains mere traces of the protoxide in solution. The above alkalis behave in the same manner towards solutions of palladium in sulphuric and muriatic acids; but the caustic alkalis redissolve the precipitate thrown down from the last acid. Ammonia and carbonate of ammonia act in a totally different manner; they precipitate only a portion from the solution of the protonitrate as basic salt; the remainder forms a double salt with the nitrate of ammonia, which is obtained in colorless prisms on evaporating the solution. If a solution of this double salt has been decanted from the precipitated basic salt, the latter does not dissolve on boiling with ammonia, but is left in the state of protoxide, containing ammonia. Solutions of the metal in sulphuric acid behave in the same manner, only that none or very little basic salt is deposited on the first addition of ammonia, and this dissolves readily on a further addition. Ammonia produces in the solution of the proto-

PALLADIUM.

chloride, at first a brown precipitate of the basic salt, which is converted on a larger addition into a peach-red double salt; and a still greater excess dissolves this precipitate to a colorless liquid, from which white prisms crystallize on evaporation. This complete solution in ammonia occurs, however, only when the chloride has been prepared without the use of nitric acid; if it contain any protonitrate, a corresponding quantity of a brown residue is left.

Highly characteristic of palladium is the reaction with protochloride of tin, with which it forms a brown precipitate, which dissolves in muriatic acid with a green color. Protochloride of tin consequently produces this green color immediately in muriatic solutions of palladium; and even when but a millionth of palladium is contained in the solution, this color is still distinct. (*Chem. Gaz.* v. 460—462.)

Oxygen. Palladium has not a very strong affinity for oxygen, but combines with it in three proportions.

Suboxide. Pd_2O . The bluish coating formed upon the metal by heating it to redness in open air. At high temperatures it is reduced.

Oxide. PdO . Obtained black and anhydrous by igniting the protonitrate; and orange as a hydrate by precipitating a solution of protonitrate with alkali. The first dissolves slowly in acids, and does not combine with alkalies. The hydrate is not only soluble in acids by heat, but is also taken up by alkalies and by ammonia. At a red heat it loses water, but does not reduce below a much higher temperature.

Binoxide. PdO_2 . Not obtained in a free state. Results as a compound from the action of potassa upon the bichloride of palladium and potassium. In this state it is brown, and retains a portion of the base. Soluble with difficulty in nearly all the acids, with yellow color. By heat it loses water, and at a higher temperature changes into protoxide, and ultimately into metal. It is sometimes called palladic acid.

Sulphuret. PdS . Formed direct. A grayish white, fusible mass, which when roasted is slowly decomposed into a reddish brown powder, the protosulphate of palladium (?), obtained also as a black powder by the action of sulphuretted hydrogen upon palladium salts. A bisulphuret has not yet been obtained.

Phosphuret. A fusible compound.

Carburet. Readily formed by heating the foil in the flame of a spirit lamp. The metal becomes very brittle.

Alloys. With tin, lead, arsenic, silver, iron, and bismuth, it forms brittle, fusible alloys; with gold, a hard alloy; with nickel a ductile alloy; with mercury a fluid amalgam.

HALOID SALTS.

Chlorine. Subchloride. Pd_2Cl . Prepared by highly heating the perchloride. Garnet-red and of crystalline fracture; deliquescent on exposure; dissolved and decomposed by water.

Chloride. PdCl . Prepared by heating the bichloride. Crystallizes in deep brown prisms, which are soluble in water. Decomposed by heat into oxichloride. Combines with other chlorides to form double salts, of which the

PALM OIL.

chloropalladiate of potassium forms golden-yellow, quadrilateral prisms. The double soda salt is deliquescent. That of ammonia is a flesh-colored powder, slightly soluble in alcohol and water, and crystallizing in colorless prisms from an excess of ammonia.

Bichloride. PdCl_2 . Obtained by dissolving and heating the metal in an excess of *aqua regia*. Is deep brown and readily decomposable by water, chlorine being disengaged and protochloride formed. It combines directly with chloride of potassium, forming a red precipitate scarcely soluble in water.

Iodide. PdI . Precipitates in brown flocculæ when solutions of protochloride of palladium and iodide of potassium are mixed together.

Cyanide. PdCy . The affinity of cyanogen for palladium is so strong that the cyanide of mercury precipitates it from all its solutions. Is white, and by calcination reduces. Forms a soluble, crystalline, double salt with cyanide of potassium.

OXYSALTS.

Sulphate. PdO, SO_3 . Brown, crystalline, deliquescent in moist air, and decomposable by water into a basic sulphate, $\text{PdO}, \text{SO}_3 + 7 \text{PdO}$. Bears a moderate heat without decomposing, but at high temperatures partially loses SO_3 , and becomes a sub-salt, and ultimately is reduced to metal.

Ammoniacal Sulphate. $\text{PdO}, \text{SO}_3 + 2 \text{NH}_3$, (or $\text{PdNH}_2 + \text{NH}_4\text{O}, \text{SO}_3$?) Crystallizes in colorless, rectangular prisms from a solution of the neutral sulphate in ammonia. At a gentle heat it becomes opaque, and at a higher temperature loses ammonia and changes into a yellow powder, $\text{PdO}, \text{SO}_3 + \text{NH}_3$.

Nitrate. PdO, NO_5 . A reddish brown, saline mass, soluble in small quantities of water, but decomposable by further dilution into a basic salt, $\text{PdO}, \text{NO}_5 + 3 \text{PdO}$, a deep brown powder. There is also an ammoniacal nitrate, $\text{PdO}, \text{NO}_5 + 2 \text{NH}_3$, in soluble, colorless, rhombic tables.

Carbonate. $\text{PdO}, \text{CO}_2 + 9 \text{PdO} + 10 \text{HO}$. When a solution of alkaline carbonate is first added to one of chloride of palladium, a bright yellow precipitate is formed, without disengagement of carbonic acid; but on continuing the precipitation, efflorescence ensues, and the deposit gradually deepens in color to brown.

Oxalate. PdO, O . A yellow powder, insoluble in water. The ammoniacal oxalate crystallizes in bronze-colored needles.

Tartrate. PdO, T . A yellow powder.

PALLADOXIDE. *Min.* The oxide PdO accompanies the metal in the platinum sand.

PALMIC ACID. } See CASTOR OIL.
PALMIN. }

PALM OIL. *Chem. Tech.* The fixed butter expressed from the fruit of the *Elais Guiniensis*. This tree is native to Africa, but is also cultivated in the West Indies and South America. Most of the oil in commerce comes from Africa.

It is yellow, but bleaches by exposure, has a violet odor, and is principally used for making palm soap, and for coloring yellow (resin) soap. When rancid, it contains free acids, and as the oil ages their amount increases, whilst the proportion of glycerin decreases, the fusing point at the same time ranging upwards from

85° to 99°. It is soluble in strong alcohol and ether, and contains 69 pts. of olein and 31 pts. of palmitin. Schwartz (*Chem. Gaz.* v. 174) also found a new acid, $C_{31}H_{31}O_4$, of fusing point 125°–126°, and in white, granular masses, or stellate flakes.

Palmitin. $C_{35}H_{33}O_4$ (*Stenhouse*). A compound of palmitic acid and GLYCERIN. Is white, crystalline, melts at 118°, dissolves readily in hot ether, but is sparingly soluble in hot alcohol.

Palmitic Acid. $C_{32}H_{31}O_3 + HO$ (hydrated). Obtained by the saponification of palmitin or of palm oil. Rochleder (*Liebig's Ann.* i. 224) found it also in coffee berries. Forms pearly scales, melts at 140°, and dissolves in alcohol.

The palmitate of potassa, $KO, Pa + Pa, HO + 2 Aq$, is an acid salt, and crystallizes in scales. According to Schwartz, when exposed to 482°–572° in the air, this acid passes into water, carbonic, and palmitonic acids.

Palmitonic Acid. $C_{31}H_{30}O_3, HO$, melts at 124°, and like the palmitic may, over a carefully regulated heat, be distilled unaltered. Its potassa salt is amorphous.

PANAX QUINQUEFOLIUM. Syn. Ginseng. A plant growing in the Northern, Middle, and Western States, the root of which, its official part, is largely used by the Chinese. It contains large quantities of starch and gum, some resin and essential oil. Its medicinal virtues are problematical.

PANCREATIC JUICE. *Chem. Physiol.* The fluid secreted by the pancreas or "salivary gland of the abdomen." Gmelin and Tiedman's analyses gives as its composition—

	Dog.	Sheep.
Water.....	917.2	963.5
Extractive matters and salts soluble in alcohol.....	36.8	15.5
Caseous matter and soda salts, soluble in water.....	15.3	2.8
Albumen and salts	35.5	22.4

PANIFICATION. See FERMENTATION and BREAD.

PAPAVERIN. $C_{40}H_{21}NO_8$ (*Merck*). See OPIUM.

PAPIN'S DIGESTER. See DIGESTER.

PARABANIC ACID. See URINE.

PARACYANOGEN. See CYANOGEN.

PARAFFIN. *Chem.* $C_{24}H_{25}$. (*Lewy*.) Found in the petroleum of Rangoon, and is also one of the products of the distillation of COAL, WOOD, and WAX. Spec. grav. 0.870. A white, fusible, waxlike, indifferent substance, crystallizable in scales from its solution in ether. Is inflammable and distils unaltered. Chlorine and anhydrous sulphuric acid both react upon it.

PARAGONITE. *Min.* The so-called talcose slate of St. Gotthardt contains no magnesia, and is not talcose, but approaches micas in composition.

PARAMALEIC ACID. See FUMARIC ACID.

PARAMENISPERMIN. See COCCULUS INDICUS.

PARAMIDE. See MELLITIC ACID.

PARAMORPHIA. See OPIUM.

PARANTHIN. See SCAPOLITE.

PARATARTARIC ACID. See RACEMIC ACID.

PARELLIC ACID. Extracted from the

LICHENS by ether. Crystallizes, and has the composition $C_{21}H_9O_{11}$, which, at 212°, is changed to $C_{21}H_9O_9$.

PARGASITE. See HORNBLLENDE.

PARILLIN. See SARSAPARILLA.

PARIS BLUE. See IRON (Prussiate.)

PARISITE. *Min.* Cryst. Hexagonal; the 2×12 -hedron; cleavage perfect, parallel to end-plane. $H. = 4.5$. $G. = 4.35$. Brownish yellow; vitreous, pearly on cleavage; transparent, translucent. In a tube it yields water and carbonic acid, becoming cinnamon-brown; infusible and phosphorescent; with borax gives a yellow glass, becoming colorless on cooling; difficultly soluble in muriatic acid with effervescence. A highly ingenious, indirect as well as direct, analysis leads to the form. $2 CaFe + RO, 2 HO + 8 (RO, CO_2)$, in which the first RO expresses CaO, LnO, DiO , and the second $RO =$ the same together with CaO .

Local. The emerald mines of New Granada. (*Bunsen. Ann. der Chem.* liii. 147.)

PAULITE. See AUGITE.

PEARL ASH. See POTASSIUM.

PEARL MICA. See MICA.

PEARL SINTER. See OPAL.

PEARL SPAR. See BITTERSAPAR.

PEARLSTONE. See OBSIDIAN. A variety from Iceland, called krablite by Forchhammer, has the form. $NaO, 2 SiO_3 + R_2O_3, 4 SiO_3$.

PEASTONE. See CALCAREOUS SPAR.

PECTIN. *Chem.* Syn. Vegetable gelatin. Formula $C_{28}H_{21}O_{24}$. The gelatin obtained by Braconnot from the juices of succulent fruits. According to Chodnew, it may be extracted from potatoes, carrots, celery, and all plants and roots containing pectose. The pectin from different sources, however, is not identical, for that from persil, and which Braconnot called *apiin*, as well as that from gentian, present properties differing from those of others. According to Fremy, pectin does not exist as such in young fruits, but is transformed from *pectose*, like gelatin from histose in bones. By the action of a nitrogenous substance, pectin is further modified into pectosic and pectic acids, and as the fruits mature, these again are changed into metapectic acid.

Prep. Grated pears are boiled, the juice filtered first through linen and then paper;—the clear liquid being treated with absolute alcohol, yields a gelatinous precipitate. By repeated washings, first with alcohol and finally with ether, and pressure after each between the hands, it becomes opaque and fibrous.

Prop. Is generally transparent, but, prepared as above, it is opaque, reddish, readily pulverizable in water. The solution is neutral to test paper, and gives a gelatinous precipitate with acetate of lead, sulphate of copper, caustic potassa, and lime, but with most other bases has no reaction. Dried at 230°, it yields 8.7 pr. ct. of ash, consisting of lime, potassa, magnesia, oxide of iron, sulphuric and phosphoric acids, and chlorine. The smallest quantity of alkali changes it into pectic acid. According to Souberain, the pectin precipitated from the juice of fruits as well as that extracted from the parenchyma, with acidulated water, consists of a soluble (pectin proper) and insoluble portion. This latter becomes soluble, however, by the prolonged action of acidulated

water, which ultimately converts pectin into *metapectin*, soluble in water and insoluble in alcohol, and into *parapectic acid*, soluble in water. Water alone, but assisted by continued heat transforms pectin into *parapectin*.

Pectic acid. $C_{25}H_{20}O_{26}$. Formed by the action of alkalies upon pectin, but exists also in the wood and bark of the plants. It is colorless, inodorous, and when dry in transparent scales, insoluble in water, but, by prolonged ebullition, becomes *parapectic* and *metapectic* ($C_{25}H_{20}O_{26}$) acids. Its alkaline salts are soluble, those with other bases insoluble. (Fremy.) See *Mucilage* under GUMS.

PECTOLITE. *Min.* Fibrous. $H. = 4-5$. $G. = 2.69$. Grayish, pearly; opaque. Behavior like the zeolites. Form. $3 (NaO (KO), SiO_3) + 4 (3 CaO, 2 SiO_3) + 3 HO$. It occurs at Monte Baldo and Monzoni, Tyrol.

PEGANITE. See WAVELLITE.

PEGANUM HARMALA. See HARMALIN.

PELARGONIC ACID. $C_{18}H_{17}O_3$, HO. Exists in the *Pelargonium roseum*, but is also one of the products of the oxidation of *Olein* by nitric acid.

PELIOM. See CORDIERITE.

PELOKONITE. *Min.* Massive, bluish black, opaque, with liver-brown streak. $H. = 3$. $G. = 2.567$. It is hydrated oxide of iron, manganese, and copper, from Chili.

PELOPIUM. *Chem.* A new metal found by Rose in the Columbite of Bodenmais, in Bavaria. It forms with oxygen an acid very analogous to tantalic acid. The chloride is yellow and fusible at 414° . For the original paper see *Chem. Gaz.* iv. 349.

PELOSIN. *Chem.* Obtained by Wiggers from the root of the *Cissampelos pareira*. Formula $C_{36}H_{21}NO_6$. (Bödeker.) By contact with aqueous vapor it becomes hydrated and insoluble in ether. Forms salts with the bases. The hydrate, under influence of air, light, and moisture, disengages ammonia, changes to yellow, and becomes, by boiling in water (*Pellatine*), of the composition $C_{42}H_{21}NO_7$. Bödeker.

PENNIN. *Min.* Cryst. Hexagonal, rhombic, with micaceous, brilliant cleavage; thin leaves transparent, flexible, not elastic. Color of sides brown; by transmitted light emerald green, by reflected blackish green. It yields water; in the pincette exfoliates, becoming yellowish white, and fuses with difficulty on the edges to a yellowish white enamel; soluble in muriatic acid with a green color, leaving silica. Form. $3 MgO (FeO), SiO_3 + Al_2O_3, 2 SiO_3 + 7 (MgO, HO)$. It occurs on the Pennine Alps.

PENTACLASITE. See AUGITE.

PEPPER. *Chem. Pharm.* The berries of the *Piper nigrum*. When deprived of the external, fleshy portion of the pericarp by maceration in water, subsequent friction and desiccation in the sun, they become *white pepper*. The constituents are soft resin, extractive, gum, bassorin, starch, alkaline and earthy malates and tartrates, woody fibre, piperin, concrete, and volatile oils. The white pepper contains much less piperin than the black.

Oil. Very fluid and colorless—obtained by distillation. Spec. grav. 0.864; boils at 333.5° . Spec. grav. of vapor 4740. According to Du-

mas, it is identical in composition with oil of turpentine. Its chlorine compound is liquid.

Piperin. $C_{40}H_{20}NO_5$ (Liebig) and $C_{34}H_{19}NO_6$ (Regnault). Forms tasteless, inodorous, rhomboidal prisms of a straw color. Fuses at 212° , dissolves in alcohol and acetic acid, but is only slightly soluble in water and ether. It is mostly neutral, but, according to Varrentrapp and Will, it forms a compound with HCl acid, which unites with bichloride of platinum. Sulphuric acid colors it red.

Prep. Poutet's method is to treat the concentrated tincture of pepper with a solution of caustic potassa of $20^\circ B.$, then diluting with water and filtering. The piperin remains upon the filter, and requires to be purified by solution in and crystallization from alcohol.

PEPPERMINT. *Chem. Pharm.* The aromatic plant *Mentha piperita*, consists of resin, bitter principle, tannin, and volatile oil.

Oil. Is distilled from the fresh herb. In dry seasons, $1\frac{3}{4}$ drachms are obtained from a pound. It is generally yellow, inclining to green, has a pungent, aromatic, cooling taste. Spec. grav. $.902$ to $.91$, and boiling point 365° . Its stearopten $C_{20}H_{20}O_2$ (Walter) is, according to Dr. Kane, isomeric with the liquid oil. The stearopten of the English oil consists of $C_{21}H_{20}O_2$. Kane.

Menthen. $C_{20}H_{18}$. The carbo-hydrogen formed by the action of anhydrous phosphoric or sulphuric acid upon the stearopten; with chlorine it yields chloride of menthen, $C_{20}H_{17}Cl$, and with nitric acid a compound of the formula $C_{14}H_9O_9$.

PEPSIN. See GASTRIC JUICE.

PER. A prefix, signifying the combination of a larger amount of one body with another; thus, peroxide of iron contains more oxygen than protoxide. The term is, however, deficient in precision.

PERCHA. See GUTTA PERCHA, and papers by Kent (*Silliman's Journ.* 1848) and by Vogel (*Chem. Gaz.* vi. 236).

PERCHLORIC ACID. See CHLORINE.

PERICLASE. *Min.* Cryst. Regular, 8-hedron, cleaving perfectly into the cube. $H. = 6$. $G. = 3.75$. Greenish, vitreous, translucent. Infusible; the powder is soluble in acids. Form. MgO , a small part being replaced by FeO . Monte Somma, Italy.

PERIDOTE. See CHRYSOLITE.

PERIKLINE. A variety of ALBITE

PERIODIC ACID. See IODINE.

PERISTERITE. } Analyzed by Thomson.

PERTHITE. }

Probably allied to feldspar, but containing too much silica.

PEROWSKITE. *Min.* Cryst. Regular; cubic cleavage. $H. = 5.5$. $G. = 4.017$. Grayish to iron-black; metallic-adamantine; opaque; grayish white streak. Infusible, and shows with fluxes the presence of titan acid. Form. CaO, TiO_2 . From Achmatowsk, near Slatoust, Ural.

PERSIAN BERRIES. *Chem. Tech.* The dried berries of the *Rhamnus infectorius*, much used in dyeing, for the rich yellow color which they yield. The coloring power is due, according to Preisser, to rhamnin.

Rhamnin. A yellowish white, crystalline, bitter powder, soluble in water, alcohol, and ether. On exposure to air it becomes yellow.

acids also turn it yellow, and alkalis dark-brown. When subjected to the action of oxidizing agents, it becomes *rhamnein*.

Rhamnein. A dark-yellow, crystalline powder, of acid reaction and forming orange-yellow salts with the bases. By exposure it darkens to brown, and to this is due the presence of red and brown matter in decoction of the berries.

PERSPIRATION. Syn. Sweat. The watery fluid secreted by the sudoriparous glands, and under the influence of high temperature, active exercise, or in certain morbid states of the system, elaborated in such quantities as to form drops upon the skin. Anselmino's analysis gives as the composition of 100 parts of the solid residue of sweat—

Substances insoluble in water and alcohol, chiefly salts of lime.....	2.0
Water-extract and sulphates.....	21.0
Spirit extract, with chlorides of sodium and potassium	48.0
Alcohol extract, acetic acid, and acetates (lactates)	29.0

These figures must be regarded merely as approximative. In 1000 parts of sweat there are contained, according to Anselmino:

Water	995.000	987.500
Epidermis and salts of lime..	100	.150
Water extract and sulphates.	1.050	2.625
Spirit extract, chlorides of sodium and potassium.....	2.400	6.000
Alcohol extract, acetates, lactates, and free acetic acid.	1.450	3.625

From 100 parts of dried residue of sweat Anselmino obtained 22.9 of fixed salts, consisting of carbonates, sulphates, and phosphates of soda and (in small quantity) of potash, chloride of sodium, phosphate and carbonate of lime, and traces of peroxide of iron.

The peculiar odor of sweat from different parts of the body is dependent in a great measure on the secretion of the sebaceous glands in those parts: thus it is well known that the sweat from the feet of many persons has a very penetrating odor, that the sweat from the axilla gives off a peculiar ammoniacal smell, and that the sweat of the external organs of generation contains and smells faintly of butyric acid. *Simon's Chemistry of Man*, p. 374.

PERU BALSAM. *Chem. Pharm.* There are two kinds of balsam of Peru, one solid, the other liquid, and both products of the same tree, *Miroxylum Peruiferum*. The first, said to resemble Tolu balsam, is the natural balsamic juice in a concrete state; the latter is obtained by boiling the bark of the tree in water.

Prop. A fragrant, syrupy liquid, of spec. grav. 1.14. Tastes bitter, and when burned emits an agreeable odor. Is soluble in a large proportion of alcohol, and contains slightly soluble, brown resin.

Cinnamic acid (CINNAMON), extractive acid, oil, or *cinnamein*, $C_{144}H_{65}O_{20}$ (*Fremy*), (CINNAMON), and *peruvim*, $C_{18}H_{12}O_2$, a light, colorless, oily fluid. According to Richter, the oil of balsam of Peru consists of a liquid oil (*myrosperium*), soluble in alcohol at 167°, and giving with potassa an acid different from the cinnamic, and an insoluble, thick oil, *myroxylin*, transformed by the alkalis into cinnamic acid and a resinous body.

PERUVIN. See PERU BALSAM.

PETALITE. *Min.* Berzelite, crystalline, cleaving into an oblique prism. H. = 6—6.5. G. = 2.42. White, gray; vitreous and glistering, pearly on cleavage; translucent. Behaves like feldspar, but if the powder be mixed with bisulphate of potassa, it tinges the flame red, from the presence of lithia; not attacked by acids. Form. 3 LiO (NaO), 4 SiO₃ + 4 (Al₂O₃, 4 SiO₃).

Local. Stockholm, Sweden, and Bolton, Massachusetts. See SPODUMEN.

PETROLEUM. *Geol. Chem.* Syn. Rock tar; Bergtheer; naphtha; Steinöl. A combustible liquid exuding from the earth with springs, or exuding direct from various formations, most frequently from the rock salt formations. It is composed of solid and liquid constituents, according to the preponderance of either of which it approaches the solid asphalt, or the fluid naphtha. By dividing the distillation, substances are obtained from it, having different properties, and composed chiefly of carbon and hydrogen in somewhat varying proportions. For the solid portion, see ASPHALT. According to Hess, the substances of different volatility have the same composition, expressed by CH. Saussure and Dumas give the form. C₃H₅. According to the fuller examinations of Pelletier and Walter, fluid petroleum or naphtha is a solution of paraffin in various liquid carbon-hydrogens; as naphtha C₁₄H₂₆, naphthen C₁₆H₃₄, naphthole C₂₄H₄₄.

Uses. Petroleum is mainly used to prepare naphtha by distillation, the residue being asphalt or pitch naphtha. The latter is mainly employed as a fluid for illumination, as on the shores of the Caspian sea, in Burmah, and in a few parts of the United States. It dissolves resins by the aid of heat, and is hence employed for varnishes. Caoutchouc swells, but dissolves to a very limited extent in it (70 to 80 in the cold, more by heat.) Refer to BITUMEN for allied substances.

PETROSILEX. See OBSIDIAN.

PETUNTSE. One of the materials employed by the Chinese in making porcelain. It is probably ground and washed feldspar.

PETROLEN. A liquid, volatile oil, C₂₀H₁₆, contained with asphalten, C₂₀H₁₆O₃, and resin in ASPHALTUM.

PEUCEDANIN. C₄H₂O. Extracted by alcohol from the root of the *Peucedanum officinale*. Is neutral, and crystallizes in white prisms, soluble in alcohol and ether, but insoluble in water.

PEUCYL.

PEUCYLEN. } See TERPENTINE OIL.

PEWTER. See ALLOY, p. 121. If its spec. grav. exceeds 7.764, it contains too much lead, and is therefore unsafe for domestic utensils.

PHÆORETIN. *Chem.* See RHUBARB.

PHAKOLITE. *Min.* See CHABAZITE, with which it has been classed; but Rammelsberg's analysis leads to the form. 2 (RO, SiO₃) + 2 Al₂O₃, 3 SiO₃ + 10 HO, which may be viewed as chabazite with a mesolite, less 1 equiv. HO.

PHARMAKANHYDRITE. *Min.* Haidingerite. Cryst. Right rhombic, prismatic, with a perfect cleavage. H. = 1.5—2.5. G. = 2.848. White, vitreous; transparent, translucent; sectile. Behavior and formula the

same as pharmakolite, less water; 2CaO , $\text{AsO}_5 + 4 \text{HO}$.

PHARMAKOLITE. *Min.* Cryst. Oblique rhombic, prismatic, with a perfect cleavage; usually fibrous. $H. = 2-2.5$. $G. = 2.64-2.73$. White, often pink from arseniate of cobalt; vitreous; translucent; opaque; fracture uneven. It yields much water; fuses in the pincette and outer flame to a white enamel; gives arsenical vapors on coal, and fuses to a translucent bead; soluble in acids. Form. 2CaO , $\text{AsO}_5 + 6 \text{HO}$. Usually associated with arsenical cobalt. See PHARMACARHYDRITE.

PHARMAKOSIDERITE. See CUBE-ORE.

PHENAKITE. *Min.* Cryst. Hexagonal, rhombic. $H. = 8$. $G. = 2.969$. Colorless, yellowish, wine-red; vitreous; transparent,

opaque; fracture conchoidal. Infusible; dissolves in the fluxes without color; fuses with a little soda to white bead, with more soda merely swells up, and is infusible. Form. 3GO , SiO_3 (or G_2O_3 , SiO_3 . *Berz.*) From Peru, and lately found near Miask.

PHENE. Syn. Benzène, BENZOLE. See also PHENYL.

PHENICIN. See INDIGO purple.

PHENYL. *Chem.* A hypothetic radical. The series to which it belongs resembles those of indigo and salicyl by its behavior to nitric acid, and by other reactions. The annexed table by Laurent presents his views as to the series of its compounds, the nucleus being a carbo-hydrogen, C_{12}H_6 , which he terms *phène*.

Phène (Benzole).....	C_{12}H_6 , $H. = \text{C}_{12}\text{H}_6$
Phenyl (unknown).....	C_{12}H_5
Oxide of Phenyl (unknown).....	$\text{C}_{12}\text{H}_5, \text{O}$
Hydrated Oxide of Phenyl (CARBOLIC ACID).....	$\text{C}_{12}\text{H}_5\text{O}, \text{HO}$
Chlorophenesis acid.....	$\text{C}_{12} \left\{ \begin{smallmatrix} \text{H}_3 \\ \text{Cl}_2 \end{smallmatrix} \right\} \text{O}, \text{HO}$
Chlorophenesis acid (Chlorindoptenic acid).....	$\text{C}_{12} \left\{ \begin{smallmatrix} \text{H}_2 \\ \text{Cl}_3 \end{smallmatrix} \right\} \text{O}, \text{HO}$
Chlorophenusic acid (Chlorinised Chlorindoptenic acid).....	$\text{C}_{12}\text{Cl}_5\text{O}, \text{HO}$
Bromophenesis acid.....	$\text{C}_{12} \left\{ \begin{smallmatrix} \text{H}_2 \\ \text{Br}_3 \end{smallmatrix} \right\} \text{O}, \text{HO}$
Nitrophenesis acid.....	$\text{C}_{12} \left\{ \begin{smallmatrix} \text{H}_3 \\ 2 \text{NO}_4 \end{smallmatrix} \right\} \text{O}, \text{HO}$
Nitrophenesis acid (Nitropicric acid).....	$\text{C}_{12} \left\{ \begin{smallmatrix} \text{H}_2 \\ 3 \text{NO}_4 \end{smallmatrix} \right\} \text{O}, \text{HO}$
Phenylamide (Anilin, Amaphenas).....	$\text{C}_{12}\text{H}_5, \text{Ad} = \text{C}_{12}\text{H}_7\text{N}$
Sulphophenic acid.....	$\text{C}_{12}\text{H}_5\text{O}, \text{HO} + 2 \text{SO}_3$

PHILLIPSITE. See HARMOTOME, *Lime*.

PHILLYRIN. A vegetable principle extracted by Carbonieri from the bark of the *Phillyrea media* and *latifolia*. Crystallizes in silvery scales, leaving a bitter after-taste. Dissolves in boiling water and hot alcohol, but is almost insoluble in ether. Sulphuric and nitric acids decompose it.

PHLOGISTON. See DEPHLOGISTICATED.

PHLORIDZIN. *Chem.* $\text{C}_{24}\text{H}_{16}\text{O}_{14}$. Extracted by boiling 80 pr. ct. alcohol from the fresh bark of the apple, plum, cherry, and pear tree. (*Koninck*.) Crystallizes in four-sided, silky prisms, of a bitter, astringent taste, soluble in boiling water and alcohol, insoluble in ether, and nearly so in cold water. Spec. grav. 1.4298. It loses water at 212° , melts at 320° , and decomposes at 384° . Dilute sulphuric acid changes it into grape sugar and *phloretin*. When moistened with ammonia and exposed to the air, oxygen and ammonia are absorbed, a blue color is acquired, and in the ammoniacal solution, upon the addition of acids, yields a red powder, *phloridzein*. Between phloridzin and salicin there is a strong analogy.

Phloretin. $\text{C}_{30}\text{H}_{15}\text{G}_{10}$. (*Stass.*) $\text{O}_{12}\text{H}_2\text{O}_4$. (*Gerhardt*.) Crystallizes in white plates, of a sweet taste, very slightly soluble in water and anhydrous ether, but very soluble in alcohol, wood-spirit, and boiling acetic acid. Melts at 356° , and decomposes. The concentrated acids dissolve it without alteration; alkaline solutions generate new compounds.

Phloridzein. $\text{C}_{42}\text{H}_{29}\text{O}_{26}\text{N}_2$ (?). Its ammoniacal solution gives a purple mass, copper-colored on the surface. Remains unaltered on exposure, and forms a splendid blue solution

with water, which is destroyed by sulphuretted hydrogen, but restored again by the absorption of oxygen.

PHLORETIN. See PHLORIDZIN.

PHOCENIC ACID. *Chem.* Syn. Delphinic acid. The volatile acid of whale oils, and found also in the berries of the *Viburnum opulus*. Recent researches have shown it to be VALE-RIANIC acid.

PHOLERITE. *Min.* The form. is Al_2O_3 , $\text{SiO}_3 + 2 \text{HO}$. See HALLOYSITE.

PHONOLITE. *Geol.* Clinkstone. A compact rock of the Trappean series, composed of a feldspar and a zeolite in variable proportion, the feldspar containing both potassa and soda.

PHOSGENE. See CARBON.

PHOSPHORESCENCE. *Chem.* A luminosity produced by certain animals, plants, and minerals. It appears that animals emit a peculiar, generally a liquid, and probably combustible substance, which oxidizing in the atmosphere or the air of water, emits light, and probably heat. Some plants emit a sudden, others a continuous light; thus the leaves of the *Phytolacca decandra* (Poke) has been observed, in September, to shine with a colored light, until midnight. Light is also emitted during the decay of animal and vegetable substances, probably due in many cases to the low combustion of this kind of fermentation. Light is also emitted by the sudden compression of gases and liquids, by the friction or pulverization of barytes, fluor-spar, dolomite, milk-quartz, loaf-sugar, and numerous natural and artificial substances. Rock-crystal, tremolite, spodumen, and many mineral substances emit light, sometimes colored, when heated

PHOSPHOROCALCITE.

In the case of some metals, organic bodies, &c., it may be ascribed to low combustion. Baldwin's, Canton's, and Homberg's Phosphorus (see these Arts.), the diamond, chlorophane, paper, and many other bodies, both simple and compound, do not shine unless previously exposed to the sun's rays, or to a strong light.

A large mass of facts has been collected in reference to phosphorescence, but we are still destitute of generalizations. Doubtless many cases may be attributed to low combustion, where more light in proportion to heat is emitted than in the case of ordinary combustion. In other cases it is probably due to electric phenomena. But there are many facts which are at present inexplicable; thus, some minerals, already oxidized, emit light when heated, without having suffered alteration of bulk.

PHOSPHOROCALCITE. *Min.* Oblique rhombic; also reniform, massive, subfibrous. H. = 4·5—5. G. = 4·205. Emerald, verdigris or dark green, with a paler streak; adamantine; translucent, subtranslucent; brittle with small conchoidal or uneven fracture. It colors flame slightly green, and if moistened with muriatic acid, blue; fuses to a black bead containing copper, and fused with lead gives a copper globule; soluble in nitric acid and ammonia. Form. $3\text{CuO}, \text{PO}_5 + 3(\text{CuO}, \text{HO})$, in which it corresponds to APHANESITE, which has the form. $3\text{CuO}, \text{AsO}_5 + 3(\text{CuO}, \text{HO})$. It occurs at Rheinbreitenbach, on the Rhine, and at Liebethen, Hungary.

PHOSPHORUS. *Chem.* Discovered by Brandt in 1669. Phosphoric acid was discovered and obtained from bones about a century later. The properties of most of its compounds were developed towards the close of the last, and beginning of the present century. It occurs in apatite and other minerals, in rocks of all ages; is an important constituent in plants, and passes from them into the animal system, in which it occurs in a more condensed form; in almost all cases it occurs as phosphoric acid.

Prep. Generally from bones. 3 pts. bone-ash, 2 pts. oil of vitriol, and 16 pts. water are digested in a lead vessel, the liquid strained to free it from sulphate of lime, &c., evaporated to a syrup, mixed to a paste with $\frac{3}{4}$ pt. charcoal powder, heated to ignition in an iron vessel, under constant stirring, and put rapidly into a retort. The retort is earthen or stoneware; a copper tube passes from the beak into a flask with two openings, where it dips slightly under water. The heat is gradually increased to whiteness, whereby the phosphoric acid and charcoal are mainly resolved into phosphorus and carbonic oxide, the former of which condenses under the water, and the latter escapes (together with some phosphorus and phosphohydrogen) through a tube in the second opening of the flask.

Other proportions of materials are also employed, as 10 pts. bone-ash and 9 pts. oil of vitriol; 1 pt. bone-ash and 1 pt. oil of vitriol. Wöhler mixed 2 pts. bone-black with 1 pt. fine quartz sand, and distilled in the same way; the phosphoric acid being set free by the silica, which forms a silicate of lime, and being decomposed by the charcoal of the black. Phosphate of lead, prepared from bones, also yields phosphorus by distillation.

PHOSPHORUS.

The drops and lumps of phosphorus are melted under water, and pressed under the same through buckskin, or redistilled at a low temperature. If it then contain arsenic, from the oil of vitriol employed, it may be removed by digestion with dilute nitric acid, until $\frac{1}{3}$ or $\frac{1}{4}$ of the phosphorus remains, which is pure. A simpler plan is to fill a slightly conical tube with cut pieces of phosphorus, to pour water on it, and place it in a vessel of boiling water. It fuses, the impurities flow out, and after cooling the phosphorus is removed in the form of a round stick. To remove a red color, it may be melted under caustic ammonia, and then under spirit of wine.

Prop. When pure, it is colorless and transparent, but usually appears yellowish and translucent; soft like wax when warm, brittle when cold. It crystallizes in regular 8 and 12-hedra; they may be obtained by dissolving it in boiling naphtha to saturation, or in hot chloride of phosphorus, and letting the solution cool; or by fusing sulphur with more than twice its weight of phosphorus, under water, and letting it cool; in all these cases a portion of phosphorus separates in crystals on cooling. Spec. grav. about 2·0; fuses between 96° and 115°, forming a clear, oily liquid, which, when slowly cooled, remains fluid even to 39°. When heated in a non-oxygenous atmosphere, it fumes at 217°, and boils at 554°; spec. grav. of vapor 4335 to 4580, by direct experiment.

It is luminous in the dark at common temperatures, and by daylight appears surrounded by a light cloud; but although it partially oxidizes in this case, yet the luminosity is not due to oxidation, at least not to oxidation alone, for it is also luminous, and gives off a light vapor in nitrogen and hydrogen gases.

It seems to enter into several allotropic conditions. When kept under water, it becomes covered with a white film, which increases slowly until the whole mass is thus transformed. It is a white, spongy mass of phosphorus alone, fusible at 109°, and not combined with water or oxygen. When phosphorus is fused under a solution of potassa in spirit of wine (of 70—80 pr. ct.), it forms a clear liquid, which remains long after the solution has cooled; but if the latter be poured off and ice-water be then thrown on, it forms a snow-white mass, that crumbles between the fingers under water. When fused phosphorus is poured into ice-water it becomes black, but returns to its usual state by fusion. Phosphorus is reddened by sunlight and the violet ray, in vacuo, nitrogen, hydrogen, carburetted hydrogen, under water, spirit, &c., sometimes forming an oxide, and sometimes not. Schroetter has confirmed Berzelius's supposition, that there is a red modification of phosphorus. He heated well-dried phosphorus in an inert gas to 464°—482° for 40 and 60 hours, when the greater part becomes carmine-red, from which common phosphorus may be dissolved out by sulphuret of carbon. It is not altered in the air, not luminous in the dark; must be heated to 490° before it inflames, and to 446° before it combines with sulphur. It is insoluble in ether, alcohol, naphtha, and chloride of phosphorus, sparingly in spts. terpentine by the aid of heat. A boiling solution of potassa disengages non-

inflammable phosphohydrogen, while the rest of the phosphorus is changed to the black variety. Phosphorus has a powerful affinity for oxygen, attracting it slowly at ordinary temperatures, and even below 32° ; and when the heat is slightly elevated, it burns with a brilliant white flame, emitting copious, dense fumes of phosphoric acid. It is therefore dangerous to handle it, except under water, where it is usually kept, and in which it is cut into pieces of required size.

Sym. P. Eq. = 31.4 ($P_2 = 31.363$, H. = 1; or 392.041, O. = 100, *Berz.*).

Phosphorus is employed in considerable quantity in the manufacture of matches. It is finely divided, by fusion, under mucilage or gum, &c., with stirring, mixed with earthy matters, clay, chalk, litharge, &c., to a paste, which becomes almost solid on cooling. The match-sticks thrown on a board, fill grooves in it singly, and being pressed by another board, are simply adjusted to the same length projecting beyond the boards. They are then dipped into the paste, and the board laid on a shelf to dry. Some matches, Golsh's, contain mixed peroxide and nitrate of lead (made by the action of nitric acid on red lead), others a small amount of chlorate of potassa, &c.; and as these substances yield some oxygen, their combustion is more ready and vivid than that of others. The match-wood is previously tipped with sulphur, or imbued with terpentine or other combustible. A water-proof match may be made by imbuing the wood with terpentine, &c., and melting the phosphorus under a thick solution of rosin, shell-lac or other resins, in alcohol, and adding a little peroxide of lead, to assist combustion.

1. *Compounds with Oxygen.* A red oxide is formed by the action of colorless or violet light. A piece of phosphorus fumes in the air, forming phosphorous acid; and although a small amount of heat is perceived during this oxidation, if several pieces be laid together, their joint heat mutually communicated, elevates the temperature so that it inflames. Inflammation produces the phosphoric acid. It may be inflamed at much lower temperatures in rarifying air, under the glass of an air-pump, if laid on cotton or strewn with powdered charcoal, sulphur, rosin, chalk, &c. Bache observed that the part on which these powders are laid rises in temperature, even to fusion of the phosphorus under the common pressure of the air, and that when placed under the air-pump and the air is rarified, it more rapidly bursts into a flame. The probable cause of this phenomena is, that these porous powders contain a portion of air condensed in them, which hastens the slow oxidation into the rapid by incipient fusion, and that it takes place more rapidly in rarifying air, because the condensed air is escaping in contact with the same points on the surface of the phosphorus, thereby bringing more oxygen in contact with it in a given time. Hence charcoal, which condenses the largest amount of air, was found to produce ignition most readily. *J. C. B.*

Oxide of Phosphorus. P_2O . A portion of red oxide is always formed when phosphorus is burned in the air, or when oxygen is passed into phosphorus fused under water. The best

method of making another modification of it is Leverrier's, in which a little terchloride of phosphorus is introduced into a glass flask with a narrow neck, then pieces of well-dried phosphorus, and lastly terchloride enough to cover the phosphorus. After 24 hours' exposure to the air, there is formed a thick white crust of phosphatic acid, under which is a yellow layer of phosphate of oxide of phosphorus. The chloride being poured off, the pieces containing the yellow compound are thrown singly into cold water, to avoid heating, and there is formed a yellow solution, which is poured off from the phosphorus and heated to 176° , when phosphoric acid goes into solution, and yellow hydrated oxide of phosphorus precipitates. The latter is rapidly washed with warm water on a filter, washed into a porcelain dish, still moist, and dried in vacuo over oil of vitriol, when it loses its water. It is a yellow or orange powder, inodorous and tasteless in dry air, oxidizing in moist air, and giving off phosphuretted hydrogen; gives with alkaline solutions phosphate of alkali and phosphohydrogen; may be heated to 570° in dry air, and takes fire at the boiling point of phosphorus; slightly soluble in water, the solution blackening salts of copper. It is soluble in alkali, which the red modification is not. The form. of the phosphate of the oxide of phosphorus is $P_2O + PO_5$.

Hypophosphorous Acid. PO . Phosphorus is boiled with barytic water until it disappears and the vapors have no longer a garlicky odor, filtered, the baryta wholly removed from the filtrate by sulphuric acid, the clear filtrate shaken for a short time with some excess of oxide of lead, filtered again, and the lead thrown down from the filtrate by sulphohydrogen. This last filtrate yields, by evaporation, a thick liquid of the hypophosphorous acid, which by heat is resolved into noninflammable phosphohydrogen and phosphoric acid, $2 PO + 3 HO = PO_5 + PH_3$. The hypophosphites are made direct from the acid, or by boiling phosphorus with the alkaline bodies; they are soluble and crystallizable, decompose by heat similarly to the acid, and have the formula $2 (MO, PO) + 3 HO$. Their solutions do not precipitate barytic or lime-water.

Phosphorous Acid. PO_3 . Bend one end of a glass tube (of $\frac{1}{2}$ inch diameter and 10 inches length) at an obtuse angle, and draw out this end to a point with a fine opening. Lay a piece of phosphorus in the small leg, and heat it to inflammation. It burns with a greenish, somewhat luminous flame, and deposits white flocks of phosphorous acid in the upright, longer leg of the tube. By attracting water in the air, it burns to phosphoric acid. The hydrated acid is formed by dissolving terchloride of phosphorus in water, $PCl_3 + 3 HO = PO_3 + 3 HCl$, and distilling in a retort to rid it of the generated muriatic acid. By evaporation to a thin syrup, it crystallizes. It is a feeble acid, uniting with 2 and 1 equiv. base to 1 of acid. The salts cannot be dried, as heat decomposes the water present, and evolves hydrogen: thus the barytic salt, $2 BaO, PO_3 + 2 HO = 2 BaO, PO_5 + H_2$. They do not oxidize in the air; they precipitate copper from the chloride by boiling; in the cold, calomel from the chloride

of mercury, silver and gold from the nitrate and chloride respectively. The acid and its soluble salts precipitate barytic and lime-water, and salts of these and other oxides; but not a dilute solution of magnesia, containing sal-ammoniac and ammonia.

Pelletier's phosphatic acid, made by the slow combustion of phosphorus in moist air, is intermediate between phosphoric and phosphorous acids, and may be, as Leverrier suggests, a phosphate of oxide of phosphorus.

Phosphoric Acid. PO_5 . The most important acid of phosphorus, occurring in some quantity in minerals, plants, and animals. It is formed by heating phosphorus or any of its oxides in the air, by oxidizing by nitric acid, or by extraction from bones. It presents three modifications of differing properties: metaphosphoric, or α phosphoric acid; pyro- or paraphosphoric, β phosphoric acid; and common phosphoric, or γ phosphoric acid.

α Phosphoric Acid, Metaphosphoric. Formed by igniting phosphorus in the air. A small tin dish, containing a piece of dry phosphorus, is placed in the middle of a porcelain plate and inflamed, and a large bell-glass immediately inverted over it. The dense white fumes of acid condense on the plate and glass, and may be increased by successively burning pieces of phosphorus in the same dish. It is inodorous, very acid, but not caustic; fusible at a red heat, and volatile below a white heat.

The hydrated acid, form. $\text{HO}, \alpha \text{PO}_5$, may be obtained by evaporating the solution of either of the other phosphoric acids, until they lose no more weight; or by exposing the preceding anhydrous acid to the air, and dissolving in water. It precipitates chlorides of barium and calcium, and nitrate of silver, and albumen white. By standing several days, more rapidly by boiling, it passes into common phosphoric acid.

β Phosphoric Acid. Pyro- or paraphosphoric. Form. $2 \text{HO}, \beta \text{PO}_5$. Its solution is obtained by precipitating pyrophosphate of soda by acetate of lead, and decomposing the filtered off phosphate of lead by sulphohydrogen. The solution may be evaporated until its temperature is 415° . Its solution throws down silver-salts, white and earthy, but does not precipitate chlorides of barium, or calcium, or albumen; it remains unaltered for a long time, but by heat passes readily into the common acid.

γ Phosphoric Acid. Common phosphoric acid. Form. $3 \text{HO}, \gamma \text{PO}_5$. *Prep.* 1. By boiling solutions of the preceding. 2. Oxidation of phosphorus by nitric acid of 1.1—1.2, forming a mixture of phosphorus and phosphoric acids, which is evaporated with the addition of portions of nitric acid, until red fumes cease to be formed, and final evaporation to remove the last portions of nitric acid. If α phosphoric acid should be formed by too strong evaporation, it may be dissolved and changed to γPO_5 by boiling. 3. Digest 100 pts. bone-ash (or bones burned and crushed) with 96 pts. oil of vitriol, diluted with 10 to 15 times its weight of water, in porcelain, stone, or lead, for one or more days, and heat at last to boiling. Strain through linen, to separate sulphate of lime; evaporate, and after cooling again strain,

to remove more of the salt. The impure acid may be purified by adding ammonia, which throws down phosphate of lime and phosphammonia-magnesia, evaporating the filtrate to dryness, and heating to fusion, to decompose the phosphate of ammonia. Or it is purified by adding alcohol before, or still better after evaporation to a syrup, filtering from sulphate and phosphate of lime and magnesia, and distilling the filtrate to regain alcohol. 4. Dissolve bone-ash in the smallest amount of nitric acid, mix and digest the hot solution with a slight excess of acetate of lead, wash the precipitated phosphate of lead thoroughly with hot water on a filter, dry, and gently ignite it to decompose organic matter; decompose 100 pts. of this salt with 33.25 pts. oil of vitriol and 400 pts. water, filter, evaporate, expel sulphuric acid by ignition in platinum, dissolve the residue in water, and precipitate lead by sulphohydrogen.

Prop. It may be evaporated to a syrup, but further evaporated becomes αPO_5 . 100 pts. of spec. grav. 1.85, contain 50 pts. acid; of 1.6, 40 pts.; of 1.39, 30 pts.; of 1.23, 20 pts.; of 1.1, 10 pts. acid. It gives a white precipitate in baryta, strontia, and lime-waters, and in acetate of lead; none in chlorides of barium or strontium, or in albumen; and with nitrate of silver, with the addition of ammonia, a yellow precipitate. It is a moderately strong acid, and being rather fixed, expels strong acids by heat.

Salts. The alkaline are soluble, the rest generally insoluble in water; all are soluble in nitric, and most of them in muriatic acid. They are very fixed in the fire, if the base be so, and mostly fuse to a glass or enamel. They are all decomposed by sulphuric acid in the wet way, and boiling potassa extracts more or less of the acid from most of them; in the dry way, they are decomposed by potassium and by charcoal, except those of the alkaline bodies, which require silica with charcoal for their decomposition.

Common, or γ Phosphates. They are formed direct from the liquid acid, or by fusing 1 eq. of any phosphoric acid with 3 eq. of base, or by precipitation with common phosphate of soda. The γPO_5 forms neutral, acid, and basic salts. The neutral have the form. $2 \text{MO}, \text{HO}, \gamma \text{PO}_5$, the acid $\text{MO}, 2 \text{HO}, \gamma \text{PO}_5$, and the basic $3 \text{MO}, \gamma \text{PO}_5$. The basic have a strong, and the neutral a feeble alkaline reaction, and the acid are distinctly acid. By expelling 1 HO from the neutral, they become pyrophosphates, and 2 HO from the acid salts, they become metaphosphates. The insoluble salts are soluble in nitric acid, most of them in acetic acid; slightly soluble in ammoniacal salts, reprecipitable by ammonia.

β Phosphates are formed direct from the liquid β acid, or by igniting 1 equiv. acid with 2 equivs. base, or by precipitating a solution of the acid or its soluble salts. The neutral salts are $2 \text{MO}, \beta \text{PO}_5$, and the acid $\text{MO}, \text{HO}, \beta \text{PO}_5$.

α Phosphates are obtained direct from the liquid α acid, or by igniting the acid α phosphates, or by precipitation. Form. $\text{MO}, \alpha \text{PO}_5$.

The analytic determination of phosphoric acid is attended with many and great difficulties which have not been overcome, in spite of num-

berless experiments made by chemists to effect this object. And yet the important part it evidently performs in the animal and vegetable economy, demands a perfect method of determination. See a critique by H. Rose, on the methods adopted, in *Chem. Gaz.* vi. 177.

2. *Hydrogen. a. Phosphuretted Hydrogen.* These two bodies do not unite directly, but when nascent hydrogen comes in contact with phosphorus, the gas is produced. It exhibits two modifications, one spontaneously inflammable in the air, the other inflaming with more difficulty. 1. The inflammable variety is obtained by the action of water on the alkaline phosphurets, most conveniently by very dilute muriatic acid on phosphuret of calcium; but the gas always contains free hydrogen. 2. By heating phosphorus in strong alkaline solutions (1 pt. phosphorus with 2 pts. strong potassa lye, or milk of lime). For lecture illustration, a small (2—4 oz.) retort is filled with milk of lime, and a piece of phosphorus of $\frac{1}{2}$ an inch length dropped into it; water is poured into the neck, the end of which is placed under the water of the pneumatic trough. Heat is applied until it comes to boiling, when bubbles of the gas begin to escape, and continue for some time. The larger the amount of phosphorus, the sooner does the reaction occur, and the more free is the gas from hydrogen. 3. Dry-slacked lime and phosphorus heated together in a small retort, yield the same gas, with more hydrogen. To avoid explosion in the retort, the latter should be tubulated, and hydrogen passed through it for some time, to expel all the air.

By the action of water on alkaline phosphurets, a hypophosphite and phosphuretted hydrogen are generated, $2\text{MP} + 3\text{HO} = 2\text{MO}$, $\text{PO} + \text{PH}_3$; by the action of acid water, $2\text{MP} + 4\text{HO} + \text{HCl} = \text{MCl} + \text{MO}$, $\text{PO}_3 + \text{PH}_3 + \text{H}_2$; by heating phosphorus and alkali, $2\text{KO} + 3\text{P} + 6\text{HO} = \text{KO}$, $\text{PO} + \text{KO}$, $\text{PO}_5 + \text{PH}_3 + \text{H}_2$.

The less inflammable gas is made, 1. by heating crystallized phosphorous acid in a retort; $4\text{PO}_3 + 3\text{HO} = 3\text{PO}_5 + \text{PH}_3$. 2. By heating phosphorous acid in a retort; $2\text{PO} + 3\text{HO} = \text{PO}_5 + \text{PH}_3$. 3. By the action of strong muriatic acid on phosphuret of calcium. 4. By heating phosphorus in a solution of potassa in somewhat dilute alcohol. These methods yield a much purer gas than those for the inflammable kind, so that the first portions in the two first processes are pure. The alcohol vapor of the last process is removed first by passing through a cooled bulb, and then through chloride of calcium. Phosphuretted hydrogen is caught over mercury or over a boiled solution of salt in water.

Both are colorless gases, of a disagreeable odor, resembling that of putrid fish; spec. grav. = 1.17—1.19; formula of each PH_3 . The former explodes spontaneously in the air, and with brilliancy in oxygen; the latter does not ordinarily explode in air, unless heated to 300° , or unless the gas be rarified, when it may explode at 68° . The cause of these differing properties is probably to be sought in different allotropic conditions of phosphorus, and it is to be observed that the circumstances which favor or retard the inflammation of phosphorus

in the air, have a similar effect upon this inflammable gas. Rose proved that they were convertible into each other in several ways, the best of which is the absorption of the gas by chlorides of tin, titanium, aluminum, and perchloride of antimony. When these compounds of the gas are brought into contact with water, the unexplosive variety escapes, whichever variety may have been absorbed. If ammonia be poured over the compounds, the self-inflammable gas escapes, whichever may have been absorbed.

Very slight causes are sufficient to prevent the explosiveness of the inflammable variety. If the mercury over which it is caught contains one grain of potassium in 50 pounds of the metal, it ceases to be explosive. The same effect results from the presence of very minute quantities of petroleum and volatile oils, by porous bodies, as gypsum, burned clay, &c. By moistening the inner surface of the glass with a little sulphuric acid, by passing in a little ether or alcohol, the explosiveness is lost in a few hours. $\frac{1}{20}$ of its volume of muriatic gas, $\frac{1}{10}$ of nitric oxide, $\frac{1}{3}$ of ammonia-gas, or $\frac{1}{2}$ sulphohydrogen have the same effect. On the other hand, an oxide of nitrogen in exceedingly small quantity, makes the unflammable variety highly inflammable.

b. *Hyduret of Phosphorus*, PH , is made by fusing phosphorus and potassium under naphtha, pressing the new compound to remove the adhering naphtha, and throwing it in water, when the hyduret separates. It is a yellow powder, not luminous, inflaming in the air when heated to 300° .

c. *Phosphohydrogen* combines with iodo and bromohydric acids, when the gases, fully dry, are brought together, to form colorless crystals, PH_3 , HI , and PH_3 HBr , which are fusible and volatile without decomposition, but decompose readily with water and ammonia, and violently with nitric, chloric, &c. acids. When passed through many metallic solutions, it precipitates metallic phosphurets.

Sulphuret of Phosphorus. Both substances fuse together in all proportions with violence, but combinations may be safely made by fusing phosphorus under naphtha, and adding sulphur gradually. The compound is more fusible and inflammable than phosphorus. It seems as if there were three definite compounds, PS , PS_3 , and PS_6 . (?)

Phosphuret of Carbon is obtained by melting crude phosphorus under water, and straining it through buckskin, which retains this orange-yellow phosphuret in an impure state. It has not been closely examined.

Phosphuret of Nitrogen. N_2P . 1. Pure terchloride of phosphorus artificially cooled is saturated very slowly with ammoniacal gas, and the compound rapidly transferred to a green glass tube, in which it is highly heated, while carbonic acid is passed over it until vapor of salammoniac ceases. 2. Vapor of terchloride of phosphorus is passed over salammoniac heated nearly to sublimation in a tube. It is a white powder, infusible, and not volatile at a red heat apart from the air. Slowly oxidized even by strong nitric acid to phosphoric acid, but deflagrates when heated with nitrates or chlorates. A hydrate, N_2P , 2HO , is formed

by saturating pentachloride of phosphorus with ammoniacal gas, extracting the greater part of the salammoniac with water, then by boiling with potassa, finally by nitric acid and water. It is a white powder, evolving ammonia by heat.

Halogens. 1. *Terchloride of P.* PCl_3 . Chlorine gas, cooled down and dried by chloride of calcium, is passed through a receiver containing phosphorus, and gently warmed, when the chloride distills from the last into another receiver. A clear liquid, of 1.45 spec. grav., boiling at 172° , fuming in the air and with an odor resembling muriatic acid, slowly decomposing with water, and combining with ammonia to a white powder, with the formula $5\text{NH}_3, \text{PCl}_3$.

2. *Pentachloride of P.*, PCl_5 , is formed by combining chlorine with the terchloride, or by burning phosphorus in a large quantity of chlorine. It is a white powder, fusible by heat under pressure, and volatilizing below 212° , decomposes violently with water into phosphoric and muriatic acids; $\text{PCl}_5 + 5\text{HO} = \text{PO}_5 + 5\text{HCl}$. Persoz has observed that by the action of nitric and nitrous acids upon it, phosphoric acid and chloroxynitrous compounds are produced. When this chloride of phosphorus is passed into sulphate of mercury, a liquid results of the form. $\text{PCl}_5, \text{SO}_3$; if passed into anhydrous sulphuric acid, the resulting liquid is $\text{PCl}_5, 2\text{SO}_2$. With dry sulphurous and phosphoric acids it unites also directly, forming $\text{PCl}_5, \text{SO}_3$ and $\text{PCl}_5 \text{PO}_5$.

3. Phosphohydrogen with subchloride of sulphur gives a yellowish syrup, $\text{PS}_{10}\text{Cl}_2 = \text{PS}_6 + 2\text{S}_2\text{Cl}$. By the action of sulphohydrogen on pentachloride of phosphorus, an oily liquid is formed, of the form. $\text{PS}_2\text{Cl}_3 = \text{PCL}, 2\text{SCL}$. By heating this sulphochloride in a retort in a water-bath, with caustic soda of medium strength, and allowing it to cool, crystals are obtained with the form. $3\text{NaO}, \text{PO}_3\text{S}_2 + 24\text{HO}$. This sulphophosphate may be viewed as $2\text{NaS} + \text{NaO}, \text{PO}_5$. Similar in composition to the sulphochloride, an oxychloride may be made by slowly decomposing perchloride of phosphorus by water; $\text{PCl}_5 + 2\text{HO} = \text{PCl}_3\text{O}_2 + 2\text{HCl}$. *Wurtz.*

4. Bromine and phosphorus unite with explosive violence, forming two compounds, the terbromide, PBr_3 , a very volatile, thin liquid, and the pentabromide, PBr_5 , a yellow, crystallizable solid, fusible and sublimable. Iodine combines similarly with phosphorus, but the definite compounds have not been studied.

PHOTIZITE. See MANGANESE SPAR.

PHOTOGRAPHY. See DAGUERREOTYPE.

PHTHALIC ACID. See NAPHTHALIN.

PHYLLITE. *Min.* A micaceous mineral, in small, black scales, from Sterling, Massachusetts. Dr. Thomson's analysis leads nearly to the form. $2(3\text{MgO}, \text{SiO}_3) + 6(\text{Al}_2\text{O}_3, \text{SiO}_3) + 5\text{HO}$, part of the MgO being KO , and part of the Al_2O_3 being Fe_2O_3 . But if the peroxide of iron be protoxide, it approaches the form. $3(3\text{MgO}, \text{SiO}_3) + 5(\text{Al}_2\text{O}_3, \text{SiO}_3) + 5\text{HO}$. These formulæ are, however, mere approximations. *J. C. B.*

PHYSALITE. See TOPAZ.

PIAUZITE. *Min.* A bituminous substance from the brown coal of Piauze, near Neustadt.

$G. = 1.22$. Blackish brown, burns with smoky flame, soluble in ether, alcohol, and caustic potassa.

PICAMAR. *Chem.* A bitter, nearly colorless oil, found by Reichenbach in tar. It forms crystalline compounds with the alkalies, without neutralizing them. Spec. grav. 1.10. Boils at 518° . Is insoluble in water, but soluble in alcohol and ether.

PICKERINGITE. See MAGNESIA ALUM.

PICOLIN. $\text{C}_{12}\text{H}_7\text{N}$. Found by Dr. Anderson in coal tar. A colorless, oily fluid, of spec. grav. .955 at 50° . Boils at 272° . Is soluble in water, but separates on the addition of potassa. Is isomeric with anilin, and forms crystallizable salts with the acids. The odor obtained by Unverdorben from animal empyreumatic oil, most probably consists of picolin.

PICQUOTAINE. A highly nutritious plant, growing in North America, and used by the Indians as food. It belongs to one of the diseases of the genus *Psoralea*, and is temporarily placed by Lamarck Picquot, who first introduced it into France, under the species *Esculentia* of Pursch, though it differs therefrom in many of its essential characters. In the proportion of $\frac{1}{2}$ or $\frac{1}{3}$ pts. farina, makes excellent bread with wheat flour. Payen's analyses gave—

Elongated root. Piriform root.

Brown bark.....	28.20	28.25
Cellulose and lignin ...	24.59	25.80
Sifted farina.....	47.21	45.95

The normal farina gave—

Nitrogen.....	0.62 pr. ct.
Water.....	12.05 “ “
Ashes.....	1.67 “ “

From which he deduced the composition of the farina as follows:—

Nitrogenous matters.....	4.09
Mineral substance.....	1.61
Starch.....	81.80
Water.....	12.50

(*Comptes Rendus*, 1848, p. 326.)

PICRIC ACID. See INDIGO, p. 723.

PICRIL. *Chem.* $\text{C}_{42}\text{H}_{15}\text{NO}_4$. Obtained by the distillation of the hyduret of sulphobenzyl (p. 314). Crystallizes in colorless octahedra, soluble in ether, but insoluble in water. By the action of nitric acid it is transformed into a yellow, crystalline powder, *Nitropyryl*, $\text{C}_{42}\text{H}_{12}\text{NO}_4\text{O}_{16}$.

PICROLITE. See SERPENTINE.

PICROMEL. See BILE, p. 318.

PICROPHARMAKOLITE. *Min.* Characters and behavior the same as pharmakolite. Form. $5\text{CaO}, 2\text{AsO}_5 + 12\text{HO}$, some of the CaO being replaced by MgO . From Riegelsdorf, Hessia.

PICROTOXIN. According to Erdmann and Marchand it contains no nitrogen. See COCCULUS INDICUS.

PIGOTITE. *Min.* A brown substance, from the granite walls of a cavern in Cornwall. Insoluble in water and alcohol; yields empyreumatic products by heat, and burns off, leaving a white residue. Form. $4\text{Al}_2\text{O}_3 + \text{C}_{12}\text{H}_5\text{O}_8 + 27\text{HO}$; it retains 10HO at 212° . It contains a peculiar acid, the mudeseous acid. *Johnston.*

PIHLITE. See PENNIN.

PIKROPHYLL. *Min.* Amorphous, foliated, deep greenish gray. $G. = 2.75$. It yields water, burns white, and shows magnesia with cobalt solution. Form. $3 \text{MgO}, 2 \text{SiO}_3 + 2 \text{HO}$, a portion of MgO being replaced by FeO . From Sala, Sweden.

PIKROSMIN. *Min.* Cryst. Right rhombic, prismatic; cleaving perfectly parallel to lateral end-plane. $H. = 2.5 - 3$. $G. = 2.6 - 2.66$. Light and dark green; pearly; subtranslucent, opaque. Yields water, and blackens, with empyreumatic odor; infusible; soluble in borax and mic. salt, leaving a skeleton of silex in the latter; shows magnesia with cobalt solution. Form. $2 (3 \text{MgO}, 2 \text{SiO}_3) + 3 \text{HO}$. See **PIKROPHYLL**. From Presnitz, Bohemia.

PIMARIC ACID. See **COLOPHONY**.

PIMELIC ACID. See **OLEIN**.

PIMELITE. *Min.* Chrysoprase, (*Klapr.*) An apple-green earth, colored by oxide of nickel. Schmidt's analysis of an earth similar in appearance, leads to the form. $2 \text{NiO}, \text{SiO}_3 + \text{HO}$, with part of NiO replaced by MgO .

PINGUITE. See **NONTRONITE**.

PINITE. *Min.* Micarelle. Cryst. Hexagonal. $H. = 2.25$. $G. = 2.757 - 2.78$. Gray, brown; resinous, glistening; opaque; uneven fracture and white streak. Yields water; fuses on the edges to a white glass, or if much iron be present to a black glass. Form. $[3 \text{RO}, 2 \text{SiO}_3 + 3 (\text{R}_2\text{O}_3, \text{SiO}_3)] + 2 \text{HO}$, in which $\text{RO} = \text{KO}, \text{FeO}, \text{MgO} (\text{NaO}, \text{CaO})$; $\text{R}_2\text{O}_3 = \text{Al}_2\text{O}_3, \text{Fe}_2\text{O}_3$. It seems to be cordierite with 2 HO . Rammelsberg suggests that cordierite may have separated into mica and pinite. From the Puy-de-dome, Auvergne; Schneeberg, Saxony; Linsenz, Tyrol; Cornwall, Aberdeenshire.

PINIC ACID. See **COLOPHONY**.

PIOTIN. See **SAPONITE**.

PIPE-CLAY. See **CLAY**.

PIPERIN. See **PEPPER**.

PISOLITE. See **CALCAREOUS SPAR**.

PISSOPHAN. *Min.* Amorphous. $H. = 1.5$. $G. = 1.93 - 1.98$. Green, vitreous, transparent; very brittle. Blackens by heat; yields alkaline water in a tube; gives acid vapors by ignition, and becomes brownish yellow; partially soluble in water, wholly in muriatic acid. Form. $2 \text{R}_2\text{O}_3, \text{SO}_3 + 15 \text{HO} (?)$, ($\text{R}_2\text{O}_3 = \text{Al}_2\text{O}_3, \text{Fe}_2\text{O}_3$). From Garnsdorf, near Saalfeld.

PISTAZITE. See **EPIDOTE**.

PISTOMESITE. See **BITTER-SPAR**. $H. = 4$. $G. = 3.4$. Form. $2 (\text{FeO}, \text{CO}_2) + 3 (\text{MgO}, \text{CO}_2)$.

PITCH. *Chem. Tech.* The residue after the evaporation of the volatile products of **TAR**. It consists principally of a resinous matter (*pyretin*), *colophony*, and pyrogenous resin.

PITTACAL. *Chem. Tech.* Obtained by Reichenbach, by the action of baryta on a certain portion of the oil of tar. The process has not yet been published. It has a golden lustre when the surface is polished, but it is of a beautiful blue color, and hence its name (from *πιττα*, pitch, and *καλός*, beautiful). Is insoluble in water, but may be suspended sufficiently to pass through a filter. Acids color it red, and alkalis restore the blue. It may probably be available as a dye-stuff.

PLASTERS. See **SOAPS**.

PLATINUM. *Chem.* First sent from South

America to Europe in 1741, as platinum sand. The sand occurs chiefly in alluvial deposits in the vicinity of gold, in Brazil, New Granada, western slope of the Ural; smaller quantities are found on St. Domingo, in S. Carolina, France, Germany, Borneo, Ava, &c. The platinum is sometimes alone, sometimes alloyed with the platinoid metals, palladium, rhodium, osmium, iridium, and ruthenium, and alloyed and associated also with gold, silver, iron, manganese, copper, lead, titanite iron, chromic iron. Among the characteristic contents are the spangles of iridosmin, flat, silvery, exceedingly hard and tough.

Prep. The well-washed sand is freed from much foreign matter mechanically; the magnetic portions extracted with the magnet, and then with dilute muriatic acid, to remove a large portion of iron. It is then heated in a tubulated retort, with a cooled receiver attached, with strong muriatic acid, to which strong nitric acid is gradually added, and an excess of the latter avoided to prevent precipitation of oxide of iridium. The residue is distilled to a syrup, dissolved in a little hot water, and the solution poured off. The distillate is added to the residue, and redistilled without ebullition. The new distillate is colorless, and contains osmic acid; it is neutralized by ammonia, charged with sulphuretted hydrogen, and suffered to stand for some days, when sulphuret of osmium separates. The residue may be retreated with nitromuriatic acid, if necessary.

The solution is boiled, to rid it of chlorine, filtered, and precipitated by an excess of a saturated solution of chloride of potassium in water, which throws down the double chlorides of platinum, iridium, and ruthenium. After washing with saturated chloride of potassium, the double chloride of ruthenium may be extracted by alcohol.

The double chlorides of platinum and iridium are dried, mixed with twice their weight of carbonate of potassa, heated gradually to beginning fusion, extracted with water, then with dilute muriatic acid, and finally on a filter with water. Most of the platinum pure is then extracted with slightly warmed, dilute aqua regia, then the rest of it with strong acid, evaporated to dryness with common salt, dissolved in water, and the oxide of iridium washed on the filter with dilute common salt and salammoniac solutions. These solutions containing iridium, are treated again like the double chlorides. The pure platinum solutions are precipitated with salammoniac (yellow, if pure), the precipitate heated gradually to ignition, and washed with water. Pure platinum remains. The balance not precipitated by salammoniac is evaporated to dryness and ignited, when more platinum is obtained. The oxide of iridium is kept as such, or reduced to metal by hydrogen.

The liquid, from which the double chlorides were separated, contains palladium, rhodium, copper, and iron, with some platinum and iridium. It is acidulated with muriatic acid, precipitated by zinc or iron, the precipitate digested with muriatic acid, washed with water, dissolved in aqua regia, exactly neutralized by carbonate of soda, and precipitated by

cyanide of mercury. The cyanide of palladium, thrown down with some copper, is dissolved in aqua regia; after washing, $1\frac{1}{2}$ times as much chloride of potassium is added as there is palladium, evaporated to dryness, adding a little aqua regia towards the last, powdered, and the cuprochloride extracted by alcohol, the remainder, palladochloride of potassium, may be precipitated as oxide, or ignited with salammoniac, when pure *palladium* remains.

After throwing down cyanide of palladium, the liquid is evaporated to dryness with muriatic acid, to expel prussic acid, the dried mass mixed and ignited with $1\frac{1}{2}$ times as much carbonate of potassa, the potash salts extracted by water, the oxide of copper by muriatic acid, the residue mixed with 5 times as much bisulphate of potassa, and kept in fusion until it begins to congeal, extracted with boiling water, evaporated and ignited with an excess of carbonate of potassa, which, after washing, leaves oxide of *rhodium*. It may be reduced to metal by hydrogen, or by a high heat, or by throwing it into fused saltpeter. The residue, after extraction by boiling with water, is again treated with bisulphate, until the latter ceases to be colored.

The residue of the first treatment with aqua regia contains iridium, &c., together with iridosmin. The latter spangles may be picked out or broken to powder in a steel mortar, and treated by Wöhler's method, which consists in mixing it with an equal quantity of common salt, and passing undried chlorine over it in an ignited tube; double chlorides of iridium and osmium, with chloride of sodium are formed, while a portion of chloride of osmium, decomposing with water into muriatic and osmic acids, the latter passes into a recipient, which is connected with a vessel containing ammonia or potassa. The solid osmic acid may be fused and run into tubes to be sealed up, or treated with alkali and decomposed, as in the first operation. The contents of the tube are extracted by water, the clear solution evaporated to one-half in a retort (in the receiver of which osmic acid is caught), the filtered liquid evaporated to dryness with the gradual addition of carbonate of soda, gently ignited, and washed with hot water, which leaves sesquioxide of iridium, with iron, osmium, and platinum. It is reduced to metal by hydrogen, the soda extracted by water, the iron by strong muriatic acid, and platinum by nitromuriatic acid. The powder is powerfully pressed, and heated in a blast furnace. The first residue yields more iridium by a similar treatment with salt and chlorine. The process might be varied so as to obtain ruthenium.

Fritzsche's method seems to be more perfect, for dissolving iridosmin and obtaining ruthenium. Equal parts of potassa and chloride of potassa are fused in a spacious iron crucible, and 6 pts. of iridosmin (not powdered) added. It swells and puffs from the escape of oxygen; in a few minutes water is poured over the black mass, gently warmed, poured into a flask, and the several washings added to the same. The residue is oxide of iridium and unaltered iridosmin, which may be separated by washing over, and the latter retreated in the same manner. The clear, yellow solution, now con-

taining osmiat and rutheniat of potassa, is treated with nitric acid (exactly to saturation), which throws down oxide of *ruthenium*, and leaves osmiat of potassa in solution. The deposit is oxide of iridium, with some osmium, and with the washed-over residue may be treated by salt and chlorine, as in Wöhler's method.

The Russian method of making massive platinum, consists in precipitating a solution of the metal by salammoniac, gently heating the double salt until all salammoniac is volatilized, rubbing the platinum sponge in a brass mortar with water, sifting it through a fine sieve, pressing the dry powder powerfully into a cast-iron cylinder, igniting the cylinder of platinum in a porcelain-fire for $1\frac{1}{2}$ days, and hammering it at a white heat. In a similar manner the large masses of platinum are made for platinum retorts, used in concentrating oil of vitriol. For smaller utensils, the sponge may be compressed into a steel mortar or an iron ring, and heated by an oxygen or hydroxygen fire. Dr. Hare employed his powerful hydroxygen blowpipe for fusing the metal, and succeeded in fusing 28 oz. at once.

Prop. Platinum is a soft, flexible metal, spec. grav. of the hammered $21\cdot2$ — $21\cdot3$, of fine wire $21\cdot4$ — $21\cdot5$. It is very malleable, and may be made into thin leaf; ductile, and may be drawn nearly to $\frac{3}{32000}$ inch thick wire, or if enclosed in silver, drawn out, and the silver dissolved, to $\frac{3}{32000}$ inch thick wire. A small quantity of iridium diminishes its softness, malleability, and ductility. Infusible in the highest furnace heats, perfectly fusible by the hydroxygen or oxygen and alcohol flames, and by galvanism.

Its resistance to many chemical agents, to oxidation in the air at any temperature, and its great infusibility, render platinum of the highest value to the scientific inquirer, for the construction of crucibles and other utensils. But in their use in the laboratory, the following circumstances should be carefully attended to:—They are attacked by chlorine and such mixtures of muriatic acid as evolve chlorine; metals heated in them nearly to their fusing point are liable to alloy with the platinum, especially antimony, arsenic, tellurium, bismuth, lead, tin, zinc, and cadmium at low temperatures, copper, silver, and nickel at higher temperatures; the oxides of these metals are dangerous if any substance (carbon, &c.) is present which may reduce them to the metallic state; even oxides of lead and bismuth are dangerous alone; phosphoric acid, some phosphates, and silicic acid, if a reducing agent be present, alkaline sulphurets and alkaline metallic cyanides are dangerous; potassa, soda, and saltpeter, by continued fusion in platinum, corrode it. But the acids and most of the oxides may be heated in platinum, provided the temperature be not too high, and the air have free access, to burn off sulphur and carbon. See CRUCIBLE.

Platinum *sponge* is made by heating the ammoniochloride of platinum to low ignition, until all salammoniac is volatilized; it becomes more dense in proportion to the heat employed. It is employed for uniting combustible gases with oxygen, at common temperatures. For more vigorous action it is used alone (see HYDROGEN,

uses of), for producing slower combination it is powdered by a wooden pestle, mixed up with clay into balls, and dried; the larger the proportion of clay, the slower the action on mixed gases. Platinum *black* is a very finely-divided metal, and exhibits a much more powerful action than the sponge. It is made, 1. by fusing platinum (or even platinum sand) with copper, zinc, or potassium, and extracting these metals in the first case with nitric acid, in the second by dilute sulphuric and nitric successively, and in the last by water. 2. By precipitating mixed solutions of platinum and iron by ammonia, drying and reducing by hydrogen, and extracting iron by muriatic acid. 3. By precipitating a dilute and acid platinum solution by zinc. 4. By precipitating a platinum solution by organic substances, as alcohol, sugar, formic and tartaric acids, &c., employing an alkali at the same time, to take up the chlorine, if the solution contained it. Liebig's method consists in dissolving chloride of platinum, PtCl_2 , in hot, concentrated potassa, in a large vessel, and adding alcohol to it while hot, with constant stirring, until effervescence from the escape of carbonic acid takes place. After settling, the liquid is poured off, and the black boiled successively with alcohol, muriatic acid, potassa, and several times with water, decanting each time, and finally drying by evaporation. It should always be washed with acid, alkali, and water.

Platinum sponge and black absorb gases powerfully, so that if extracted by heat and the air-pump, and then suddenly admitted, the rapid absorption may ignite the platinum. According to Döbereiner, it absorbs oxygen and not nitrogen from the air, and Liebig's black is said to absorb 250 times its volume of oxygen, which gives a compression of 1000 atmospheres, calculating the pores at $\frac{1}{4}$ th of the volume, (compare this with charcoal, under ABSORPTION.) It unites gases, as oxygen and hydrogen, powerfully; and even fine platinum wire, heated to 122° , will unite them so rapidly as to become ignited; it unites sulphurous acid and oxygen to sulphuric acid; it oxidizes alcohol to acetic acid, which may even go to carbonic acid and water; sponge and fine wire, in the vapor of alcohol, become ignited, and produces acetic and acetous acids; black, in the vapor, produces acetic acid and acetal; from methylic alcohol it produces formic acid. It also produces metamorphoses in compounds: in a mixture of saltpeter with potassa and alcohol, it produces carbonic acid and ammonia; in a mixture of cyanogen and hydrogen, with heat, it yields cyanide of ammonium, &c. When, after use, the black has lost much of its power, it may be restored by boiling with sulphuric acid, washing with water, and then ammoniacal water.

Sym. Pt. Eq. = 99, (= 98.68, H. = 1 or 1233.499. O. = 100, Berz.)

Compounds. 1. *Oxygen.* *Oxide of Platinum*, PtO , is obtained by decomposing chloride of platinum, PtCl_2 , by a solution of potassa, gently warmed, and washing. It is a black, voluminous powder, losing its water by a gentle heat, and its oxygen by ignition. It dissolves in acids to salts, which are red, brown, and colorless, precipitable by sulphohydrogen, and solu-

ble in an excess of sulphuret of ammonium; colored reddish brown without precipitation, by tin salt; precipitated black by nitrate of suboxide of mercury; excess of ammonia throws down green chloride of platinum and ammonia; carbonate of potassa or soda a brownish precipitate and brownish red solution; not affected by potassa, carbonate of ammonia, phosphate of soda, cyanide of mercury, yellow or red prussiate of potash, or oxalic acid.

Platinum-oxide-ammonia. The sulphate ($2\text{NH}_3, \text{PtO}, \text{SO}_3$) is precipitated by barytic water, the filtrate evaporated apart from air, and then in vacuo to crystallization. Its formula is $2\text{NH}_3, \text{PtO}$, or $\text{NH}_3\text{Pt} + \text{NH}_4\text{O}$; of the crystallized, $\text{NH}_3, \text{PtO} + \text{NH}_4\text{O}$. It acts as a strong alkaline base, is deliquescent, forms neutral salts with acids, from which bases again precipitate it unaltered. By keeping it heated to 212° , it loses 1 equiv. HO and ammonia, forming NH_3, PtO (or $\text{NH}_3\text{Pt}, \text{O}$), which is insoluble in water and ammonia, and forms explosive, insoluble salts.

Binoxide of Pt., PtO_2 , is precipitated as a hydrate from the nitrate, by potassa, or from heated sulphate by carbonate of lime, and extracting the lime from the precipitate by acetic acid, and then water. A brown powder, which loses water by heating and becomes the black oxide, which further heating resolves into metal and oxygen. The salts of this oxide are made by adding to bichloride of platinum an alkaline salt, sulphate, &c., as long as the double potassachloride precipitates. The solutions are yellow or brown, and reducible to metal (*black*) by metals and organic bodies; precipitable black by sulphohydrogen, and soluble in excess sulphohydrate of ammonium; by iodide of potassium, brown or a brown red coloring; tin salt a similar coloring, and gradually a precipitate; nitrate of suboxide of mercury, reddish yellow precipitate; in the chloride solution, potassium and ammonium chlorides give the yellow, double alkaline chloride. They are not precipitated by common salt, phosphate of soda, oxalic acid, nut galls; nor by phosphuretted hydrogen or cyanide of mercury, which distinguishes it from palladium, nor by copperas, which distinguishes it from silver, gold, and palladium.

2. *Sulphur.* *Sulphuret of Pt.*, PtS , is formed by precipitating a protosalt by alkaline sulphuret, or by igniting the sponge and sulphur together. A blue black powder, losing all sulphur by ignition in the air, alone or with zinc, chlorate, or nitrate of potassa.

Bisulphuret of Pt., PtS_2 , formed by precipitating the binoxide salts by alkaline sulphuret, or by heating 3 pts. platinum-salammoniac with 2 pts. sulphur, is a black gray powder, similarly decomposed to the preceding.

3. *Phosphuret of Pt.* Phosphorus and charcoal, or phosphorus alone, heated with platinum, yields a phosphuret, white, metallic, brittle, and fusible.

4. *Nitruet of Pt.* When platinum-oxide-ammonia is kept at 356° in a retort, ammonia and water pass off, leaving Pt_3N , which at 374° is suddenly resolved into nitrogen and platinum.

5. *Alloys.* Platinum readily unites with

other metals by heat, and the union is often so violent as to evolve light and heat; the alloys are quite fusible. The alloy with potassium or sodium is shining, brittle, decomposed by water; with antimony steel-gray, brittle, crystalline; with arsenic, brittle and very fusible (in both these last the metals may be oxidized by heating in the air, leaving malleable platinum); with molybdenum and tungsten, gray, brittle; with bismuth and zinc, bluish, brittle, very fusible; with lead, reddish, brittle; with tin and cadmium, silver-white; with copper, pale-yellow, malleable; with nickel, yellowish white, malleable, magnetic; with iron, hard, malleable (99 pts. iron to 1 pt. platinum is not attacked by common nitric acid); with steel, 9 pts. Pt + 2 pts. steel a perfect alloy, spec. grav. 15.88, not tarnishing in the air;—1 Pt + 1 steel, spec. grav. 9.862, receives a good polish;—1 Pt + 67 steel, well adapted to cutting tools;—1 Pt + 100 steel, less hard, but tougher than silver-steel;—1 Pt + 200 steel, adapted to razors; it also unites with gold, palladium, and iridium.

Haloid Salts. Chlorine. 1. *a. Chloride of Pt.*, PtCl_2 , obtained by heating the bichloride to the melting point of tin; is resolved by higher heat into chlorine and platinum, and by boiling aqua-regia into bichloride, soluble in strong muriatic acid. By adding chloride of potassium, sodium, or ammonium to this last solution, the red, double salt, $\text{KCl}(\text{NaCl} \text{ or } \text{NH}_4\text{Cl}) + \text{PtCl}_2$, is obtained.

b. Chloride of platinum and ammonia is obtained by dropping the acid solution of the chloride into hot ammonia, or by passing sulphurous acid into bichloride until it ceases to precipitate with salammoniae, heating to boiling, and super-saturating with ammonia; green crystals separate from the cooling solution, insoluble in water, alcohol, and muriatic acid, with the form. $\text{PtCl}_2 + \text{NH}_3$. By boiling them with water for some time, they pass into a yellow modification of the same composition.

c. Reiset's chlorammonium-platinamid has the same composition, with the addition of 1 equiv. ammonia, viz., 2NH_3 , PtCl_2 , or $\text{PtNH}_2 + \text{NH}_4\text{Cl}$. It is prepared by boiling the above green variety with ammonia (replacing some of the latter as it evaporates) until it is dissolved. (*Reiset.*) Or by dissolving PtCl_2 in muriatic acid, saturating with carbonate of ammonia, heating the liquid with the gradual addition of the carbonate of ammonia until the red color of the liquid (PtCl_2 , NH_4Cl) has passed into yellow, when a green body separates, from which the liquid, still boiling, is filtered. The cooling solution deposits the above yellow, NH_3 , PtCl_2 , and the new salt is precipitated from the solution by alcohol. By warming the NH_3 , PtCl_2 with ammonia, it passes into the same body. (*Peyrone.*) It is white, soluble in water, crystallizable, and forms salts with other acids besides the muriatic. These salts are conveniently prepared by adding to a strong solution of the chloride, 2NH_3 , PtCl_2 , another acid, when the salt either precipitates or soon separates in crystals. These salts are neutral, generally colorless, and have no taste of platinum. The form. of the nitrate is $\text{NH}_3\text{Pt} + \text{NH}_4\text{O}$, NO_3 , or 2NH_3 , PtO , NO_3 . *Reiset & Peyrone.*

d. Gros's base, platinochloramid-oxide of ammonium is only known in combination with acids. The nitrate is formed by digesting the green chloride of platinum and ammonia (*b*) with nitric acid, until it becomes white, dissolving in hot water to saturation, and crystallizing; several crystallizations purify it; form. $\text{NH}_2\text{PtCl} + \text{NH}_4\text{O}$, NO_3 . The sulphate and oxalate are made by adding these acids to the nitrate, and crystallizing; the phosphate, carbonate, formate, and tartrate, by adding the alkaline salts to the nitrate, and the chloride, $\text{NH}_2\text{PtCl} + \text{NH}_4\text{Cl}$, by adding common salt or muriatic acid.

2. *Bichloride of Pt.* Obtained by dissolving the metal in aqua-regia, and evaporating in a water-bath to dryness; if evaporated too strongly, some chloride is produced, which gives a darker solution. It sometimes crystallizes with 10 HO. Form. of the dry salt, PtCl_2 , containing 58.3 pr. ct. platinum. Reddish brown mass, dissolving in water with a yellowish hue, soluble in alcohol and ether, reduced by heat first to chloride, and then to metal. It forms double salts with metallic chlorides, of which those with chloride of potassium, ammonium, and sodium are the most important. The two former, $\text{KCl} + \text{PtCl}_2$, (containing 40.51 pr. ct. platinum + 30.52 $\text{KCl} + 28.97 \text{ Cl}$), and NH_4Cl , PtCl_2 (with 44.36 pr. ct. platinum), are lemon-yellow (orange in crystals), slightly soluble in cold water, pure and acidulated, more so in hot, and still more in alkaline water, insoluble in alcohol of 60 or more pr. ct.; the potassium salt is decomposed only by a strong heat, more readily in hydrogen; the ammonium salt more readily decomposed. The sodium double salt, NaCl , $\text{PtCl}_2 + 6 \text{HO}$, is crystallizable and readily soluble in water and alcohol. The salt of barium has 4 HO, of strontium and of calcium 8 HO; those of magnesium, manganese, iron, zinc, cadmium, nickel, cobalt, and copper have 6 HO, and are isomorphic, hexagonal prisms; they are yellowish, soluble, some of them deliquescent; there is a yellow, basic, insoluble silver double salt.

3. *Bibromide and Binioidide of Pt.* PtBr_2 and PtI_2 . Formed by solution of platinum in nitric mixed acid with bromhydric or iodhydric acid; dark brown and black, crystalline, forming double salts with metallic bromides and iodides. The iodide, PtI , is formed by heating chloride of Pt with iodide of potassium in solution; it is a black powder, combines with ammonia by boiling the following amid-salt, forming PtI , NH_3 . The iodammonium-platinamid is obtained from the sulphate of Reiset's salt (1. c.), and iodide of barium; formula NH_4I , PtNH_2 . The bromide and its amid salt are similar and similarly formed.

4. *Bifluoride*, PtF_2 , forms double salts with alkaline fluorides, which are uncrystallizable.

Oxysalts. 1. *Sulphate of Oxide of Pt.* is obtained by precipitating a solution of the oxide in potassa, by exactly neutralizing with potassa, and dissolving the precipitated oxide in dilute sulphuric acid; this and the nitrate, similarly made, form brown solutions. They unite with ammonia, when the ammoniacal chloride (1. b.) is precipitated by sulphate or nitrate of silver.

PLATINUM.

2. *Sulphate of Binoxide* is obtained by decomposing bichloride by sulphuric acid; it is soluble and crystallizable.

3. *Sulphite of Oxide* is obtained by passing sulphurous acid through water, suspending the oxide; it forms double salts with soda and ammonia. There is also a sulphite of binoxide.

4. *Nitrate of Binoxide* is obtained direct, or by decomposing the sulphate by nitrate of baryta. It forms basic double salts, with potassa and soda.

PLATINUM. *Min.* Generally in rounded, irregular grains. Cryst. Regular, cubic. $H. = 4-5$. $G. = 17-19$. Metallic, steel-gray, ductile, sometimes magnetic from the presence of iron. Soluble in nitro-muriatic acid; unaltered by blowpipe, heat, and fluxes. See **PLATINUM**, *Chem.*

PLEONAST. See **SPINELL**.

PLINIAN. *Min.* A mineral described by Breithaupt, belonging to the Oblique rhombic system, of $G. = 6.3$, from St. Gotthardt, Ehrenfriedersdorf, &c., but identical in composition with **ARSENICAL PYRITES**, which is therefore dimorphic.

PLUMBAGIN. *Chem.* A neutral substance, obtained from the *Plumbago Europaea*, in orange-yellow crystals. Its hot, aqueous solution is reddened by alkalis, but acids restore the yellow color. Is also soluble in alcohol and ether.

PLUMBAGO. See **GRAPHITE**.

PLUMBIC OCHRE. *Min. Ger.* Bleiglätte. $G. = 8$. Massive, lemon-yellow, and fawn colored; opaque. It fuses readily on charcoal, and yields metallic lead. Soluble in nitric acid, usually with effervescence, from a little white lead, and sometimes leaves a little brown oxide, from the presence of minium. It occurs at Mine à la Motte, Madison Co., Missouri, and at Austin's mines, Wythe Co., Virginia.

PLUMBOCALCITE. *Min.* It is only a carbonate of lime, replaced by a small quantity (2-7 pr. ct.) of carbonate of lead. From Wanlockhead, &c.

PLUMBORESINITE. *Min.* Syn. Plumbogummite, Plombgomme, Bleigummi, Gummispath. In powder and columnar aggregations. $H. = 4-4.5$. $G. = 4.88-6.4$. Yellowish and brown; resinous; translucent; resembles Arabic gum. Yields water in a tube, and decrepitates; on coal it whitens, swells, and partially fuses in a strong fire; soluble in fluxes; reduced by soda to lead; cobalt solution gives a pure blue; soluble in nitric acid. Berzelius makes it 6-hydrous bin-aluminate of lead, but Damour's analysis gives the form. $3 PbO, PO_5 + 6 (Al_2O_3, 3 HO)$. From Huel Goet, &c.

PLUMBOSTIB. See **BOULANGERITE**.

POLIANITE is **PYROLUSITE**.

POLLEN. *Bot.* The pulverulent matter enclosed in the anthers of a plant.

POLLUX. *Min.* Crystalline. $H. = 6$. $G. = 2.87$. Colorless, vitreous, transparent. Gives a little water in a tube; becomes white and opaque by ignition; thin splinters are rounded to a blemmy enamel, coloring the flame reddish yellow from lithia. Soluble in muriatic acid, leaving earthy silica. Plattner found in it 16.5 pr. ct. potassa and 10.5 soda.

POLYHYDRITE.

The analysis is imperfect, but Berzelius gives the probable form. $RO, SiO_3 + NaO, SiO_3 + Al_2O_3, SiO_3$. There is probably some error in the analysis, or the large percentage of alkali would render it more fusible. (*J. C. B.*) From the granite of Elba, associated with tourmalin and beryl.

POLYADELPHITE. See **GARNET**.

POLYARGITE. *Min.* In grains and foliated masses. $H. = 4$. $G. = 2.7$. Colorless, red, violet; pearly on cleavage plane; sub-transparent. It seems to be the same as Rosellan. From the granite of Tunaberg, Sweden.

POLYBASITE. *Min.* Eugenglanz. Cryst. Hexagonal. $H. = 2-3$. $G. = 6.214$. Black, metallic, opaque. It gives the odor of sulphur heated in an open tube, a coating of antimony on coal, and mixed with soda and coal, the odor of arsenic. Yields a large bead of silver by cupellation. Form. See **ANTIMONIAL ORES**; a general formula would be $RS_3 + 8 RS$, in which the 1st R = As and Sb, and the 2d R = Ag and Cu. From Guanaxuato, Mexico.

POLYCHROITE. See **SAFFRON**.

POLYCHROME. *Chem.* Form. $C_{16}H_9O_{10}$ (*Trommsdorff, Jr.*). A kind of coloring matter obtained from quassia-wood, horse-chestnut, and several other plants. Crystallizes from solution in a mixture of alcohol and ether. Its solution in hot water gelatinizes on cooling. A solution of 1 pt. in 1,500,000 of water, exhibits by reflected light a beautiful play of colors, which is heightened by alkalis, and destroyed by acids.

POLYCHROMIC ACID. See **ALOETIC ACID**.

POLYCRASE. *Min.* Cryst. Right rhombic. $H. = 5.5-6$. $G. = 5.1$. Black, very lustrous; brown streak. Infusible, giving yellow glasses with the fluxes in the outer flame, and brown in the inner. Soluble in heated sulphuric acid. It contains columbic and niobic acids, and oxide of uranium. In granite, Hitterø, Norway.

POLYGALA SENEGA. Syn. *P. Virginea*. The root contains polygalic, virgineic, pectic, and tannic acids, yellow coloring and bitter matters, gum, albumen, cerin, fixed oil, and salts.

Polygalic Acid. Syn. Senegin, Polygalin. $C_{11}H_{15}O_{11}$. The active principle of the root. A white, odorless, poisonous powder, soluble in hot water and alcohol, but insoluble in ether and the oils. It is a weak acid, and forms salts of which those with the alkalis are soluble, but not crystallizable.

Virgineic Acid. A volatile, oily liquid, analogous to valerianic acid, of red color, disagreeable, pungent odor, and acrid taste. Is insoluble in water, but soluble in alcohol, ether, and caustic potassa.

POLYHALITE. *Min.* Blödit. Cryst. Right rhombic, and fibrous. $H. = 2.5-3$. $G. = 2.77$. Flesh-red, yellowish; resinous; translucent, opaque; taste slight, bitter, astringent. It yields water, and fuses on coal to reddish globules; soluble in borax to a dark-red glass. Soluble in water, leaving gypsum. Form. $(KO, SO_3 + MgO, SO_3 + HO) + 2 (CaO, SO_3) + HO$. From salt mines of Ischel, Aussee, &c.

POLYHYDRITE. *Min.* Liver-brown, vitre-

ous, opaque. $G. = 2.12$. It is a hydrous persilicate of iron, from Breitenbrunn in Erzgebirg.

POLYLITE, allied to HORNBLÉNDE or AUGITE.

POLYMERIC ISOMORPHISM. *Min.* T. Scheerer has endeavored to prove that a particular kind of isomorphism plays an important part in the mineral kingdom, viz.: that 1 equiv. of magnesia or its isomorphous bases, MnO , CoO , &c., may be replaced by 3 equivs. of water, without alteration of form. Thus, chlorophaite has the form. $3 FeO$, SiO_3 , and some serpentines are nearly $2 SiO_3 + 5 MgO + 3 HO$. But if $3 HO = MgO$, the proportion becomes simply $2 SiO_3 + 6 MgO$, or $3 MgO$, SiO_3 . So that using R for the radicals, the general formula for serpentine, chlorophaite, deweylite, dermatin, &c., would be $3 RO$, SiO_3 ; but Scheerer encloses the isomorphic expression RO in a parenthesis, signifying the replacement above alluded to, writing the form. $(RO)^3$, SiO_3 . He also assumes $CuO = 2 HO$, and these views are applied to phosphates, arseniates, sulphates, and borates.

Now, although simpler formulæ result from this theory, yet it is a mere theory, and not well grounded, for he admits that it is not of universal application, and that the water in zeolites is that of crystallization. But if $MgO = 3 HO$ in compounds, they ought to have the same crystalline form alone. Moreover, most serpentines cannot be brought under his formula, without rejecting some of the results of analysis, and the same may be said of other silicates. Rammelsberg has put together the results of 13 analyses of serpentine, from which the proportions of $MgO : HO : SiO_3$ are $9 : 6 : 4$, and by putting $6 HO = 2 MgO$, the formula would be $11 MgO$, $4 SiO_3$, which is incompatible with Scheerer's formula. Moreover, his illustrations are chiefly taken from minerals, which play an important part in pseudomorphism, and are often of doubtful form and of variable composition.

POLYMERISM. See ISOMERISM.

POLYMIGNITE. *Min.* Cryst. Right rhombic, prismatic, terminated by the 8-hedron. $H. = 6.5$. $G. = 4.77 - 4.85$. Black; sub-metallic, brilliant; opaque; brilliant conchoidal fracture, and dark brown streak, unaltered alone by heat; gives iron reaction in borax, and with mic. salt a bead becoming reddish in the inner flame. Decomposed in powder by oil of vitriol. It contains TiO_2 , ZrO_2 , Fe_2O_3 , Mn_2O_3 , Ce_2O_3 , CaO , YO ; but the difficulties of the analysis prevent the construction of a formula. Friedricksvärn, Norway, and Beverly, Massachusetts.

POLYPHERITE. See PYROMORPHITE.

POLYXEN. See PLATINUM.

POMPHOLIX. See OXIDE OF ZINC.

POONAHILITE. *Min.* Cryst. Right rhombic. $H. = 5 - 5.5$. $G. = 2.162$. White, vitreous, transparent, translucent. Behavior like MESOTYPE. Form. $3 (CaO, SiO_3) + 5 (Al_2O_3, SiO_3) + 12 HO$. It may be viewed as 3 equivs. scolezite (mesotype) + $2 (Al_2O_3, SiO_3) + 3 HO$. From Poohnah, Hindostan.

POPULIN. *Chem.* Exists in the bark and leaves of the *Populus tremula* and other species of poplar. Is very analogous to salicin, though

differing in many properties. Crystallizes in white, silky needles, of a sweetish taste. Is soluble in alcohol and in 70 pts. of boiling water, and on distillation yields an oil which deposits benzoic acid. Sulphuric acid reddens it.

PORCELAIN CLAY. See CLAY and KAOLIN.

PORCELAIN JASPER. *Geol.* Clay beds which have been semivitrified by igneous rocks. A fine locality in Hirschberg, near the clay-beds, whence Hessian crucibles are made.

PORCELAIN SPAR. *Min.* In square prisms. $H. = 5.5$. $G. = 2.65 - 2.68$. White, yellowish; pearly on cleavage plane; translucent. Puff by heat, fusing to a clear, blebby glass. Decomposed by muriatic acid. According to Fuchs's analysis, the form. is $NaCl + 4 (CaO, SiO_3 + Al_2O_3, SiO_3)$. From Obernzell, in Bavaria.

PORPHYROXIN. See OPIUM.

PORPHYRY. *Geol.* A feldspathic rock, characterized by distinct and disseminated crystals of feldspar. Hence granite, syenite, and trap may be porphyritic. It consists of both potassa and soda feldspars, of silex, oxide of iron, alumina, &c.

POTASH COPPERAS. See 5, under COQUIMBITE.

POTASSIUM. *Chem. Ger.* Kalium. The name potassium is from potash, and this from the solution of ashes of plants, boiled down in iron pots. A crude salt is still called potash and pearlsh. Kalium is from the general word *alkali*, by which the Saracens denoted the ashes of sea-plants, and subsequently others the ashes of land plants, no difference being known between potash and soda. Their different natures were first shown about the middle of the last century, and the names vegetable (potash) and mineral (soda) alkali, at first used, gave place to potash and soda. The metal potassium was first separated by H. Davy, in 1807. It occurs in the ashes of land plants and of animals, and is therefore a constituent of all soils, in nearly all clays, and sands, and their rocks; in large quantity in feldspar, and in smaller quantity in many other simple minerals; in minute quantity in most limestones; in coal and iron ores; in sea-water and most mineral waters.

THE METAL AND ITS NON-SALINE COMPOUNDS.

1. *Potassium. Prep.* It was first prepared by Davy, by the action of a powerful galvanic battery on caustic potassa, and subsequently by Gay-Lussac and Thénard, by igniting caustic potassa with iron filings and wire in an iron tube. The best method is that of Brunner, modified by Wöhler, which consists in igniting a mixture of charred cream of tartar and charcoal in a mercury flask (of wrought iron). 4 pts. purified potash may be dissolved in water, 1 pt. fine and then 1 pt. coarse charcoal stirred in, and the whole evaporated to dryness; and such a mixture answers as well as the preceding. The flask is laid horizontally in the fire, an iron tube (5 inches long) being screwed in the opening. The receiver consists of two copper vessels, the lower one open above and larger, and $\frac{1}{3}$ or more filled with naphtha; the upper one open below and passing into the other, so that the naphtha seals

its interior from the air. This upper one has three openings towards its upper part, into one of which the iron tube of the flask is to be passed, and opposite it another, closed by a cork, which is now and then opened to insert an auger or wire, to clean out the iron tube; the third is designed for the escape of carbonic oxide, &c., and may be provided with a tin tube passing into a cold iron vessel, to condense croconic acid from the gas. The larger vessel is set in a shallow water vessel to cool it. The charged flask is heated until greenish vapors and self-igniting gas appear; the iron tube is then joined to the receiver, and a strong heat given, but not sufficient to burn away the iron flask too rapidly. The tube must be bored as often as it appears to be stopping; if stopped, and if it cannot be opened by the auger, the heat should be removed, for if opened after stopping, there is great danger of compressed gas in the flask suddenly bursting through and driving out ignited potassium. The operator should therefore stand on one side, and have his hands protected. When the operation has ceased, the water vessel is removed, the receiver separated from the iron tube, and the openings closed with corks. After cooling a little the inner vessel is taken out, the deposits quickly moistened with naphtha, and scratched down into naphtha. If the naphtha take fire, it is extinguished by covering the whole with a cloth or boards. The black, carbonaceous mass is either redistilled to gain potassium, or by solution in water is used for preparation of rhodizionate and croconate of potassa. Potassium and the black substance is also extracted from the iron tube, in a similar manner. The apparatus should not be allowed to stand many hours before collecting the potassium, as the moisture of the air condensing in it, may give rise to dangerous explosions. In the best operations, nearly one-half of the potassium present in the potash may be obtained. The metal thus obtained, and the coaly matter, may be purified by distillation from an iron retort, the metal being received under naphtha as before. It is always preserved in naphtha.

Prop. A silver-white, lustrous metal, crystallizing in cubes by sublimation; spec. grav. 0.865; brittle at 32°, ordinarily like wax, perfectly liquid at 186°, volatile at low redness in green vapors. One of its most striking properties is its affinity for oxygen, which it attracts from the moisture of the air, and soon becomes white. When thrown on water it instantly inflames with a purplish light, giving off light vapors, and continues floating on the surface until nearly all consumed; in this action it decomposes water, taking up oxygen, and giving off hydrogen, which inflames from the intense heat evolved, while a portion of the metal volatilizing gives the purple hue to the flame; $K + HO = KO + H$. By its powerful affinity for oxygen, it decomposes the mineral acids and their salts, except borates, nearly all the oxides of the proper metals, and by its affinity for chlorine the chlorides of the earthy metals. Sym. K. Eq. = 39.11, (488-856, O. = 100).

2. *Oxygen.* a. *Oxide of P.* Syn. Potassa; when hydrated, Caustic Potash. Ger. Kali.

The dry oxide may be formed by igniting the peroxide. The *hydrate* or caustic potassa is usually made from the carbonate (potash and pearlash, crude or purified), by the action of hydrate of lime; $KO, CO_2 + CaO = KO + CaO, CO_2$; the carbonate of lime is insoluble, and the caustic alkali remains in solution. To make pure potassa, 3 pts. of pure carbonate of potassa are brought to boiling in 12 pts. water, and lime gradually added (from 2 pts. lime previously slacked with 6 pts. water). It is boiled a few moments after each addition of lime, and after adding the whole, boiled for $\frac{1}{2}$ hour. A little is then filtered off, and tested with lime water, for carbonate of potassa; if the latter be present more lime must be added, and the whole boiled again. After settling, the clear solution is syphoned into corked bottles, and the residue once or twice boiled with water to extract all the potassa, settled, and drawn off. The clear liquor of the bottles is again drawn off into an iron kettle, rapidly boiled, and if it become cloudy, again drawn into bottles to settle. It is finally evaporated in a silver capsule, until the oily liquid begins to rise in white vapors, and poured into moulds or on a plate, apart from carbonic acid. During the evaporation (and filtering, if that be employed instead of decantation), carbonic acid will be absorbed from the air, but the carbonate floats on the oily liquid, and may be removed.

A pure potassa may likewise be obtained from common or partially purified potash and pearlash, by proceeding with the lime and potash as above, evaporating to an oil, decanting into bottles, and shaking it up with $\frac{1}{2}$ alcohol. By standing it forms two strata, the lower containing oxide of iron and silex, with an aqueous solution of carbonate, sulphate, and muriate of potassa, the upper stratum containing caustic potassa and a little chloride. The upper stratum is distilled to save alcohol, then evaporated, and cast as before.

Pure potassa may also be obtained by dissolving sulphate of potassa in concentrated barytic water, then adding the latter carefully until it no longer throws down the sulphate. The clear liquid is evaporated as before.

Caustic lye, for soap-boiling, is made by rendering 15 pts. common potash caustic by 7 to 13 pts. of caustic lime, previously slacked. A good method is to mix the dry-slacked lime and ash together, to drench with water, and blow steam through the mixture. The common sticks of caustic potash are very impure, and cannot be employed in fine chemical operations.

Prop. Fused potassa is a simple hydrate, KO, HO, with 84 pr. ct. dry potassa; it is white, hard, and tolerably brittle, fusible below, volatile above redness, and dissolving in water with the evolution of much heat. By cooling a concentrated solution, crystals are obtained of the formula KO, HO + 4 HO. 1 pt. hydrate will dissolve in $\frac{1}{2}$ pt. water, with which, and even more water, it forms an oily liquid. Even when quite dilute, it feels very soapy between the fingers. The following table, by Tünnermann, shows the quantity of dry potassa in solutions of different specific gravities:—

POTASSIUM.

Spec. grav.	Potassa in 100.	Spec. grav.	Potassa in 100.
1.330	28.29	1.144	14.15
1.313	27.16	1.131	13.01
1.297	26.03	1.118	11.88
1.280	24.89	1.106	10.75
1.265	23.76	1.094	9.62
1.249	22.63	1.082	8.49
1.234	21.50	1.070	7.36
1.227	20.94	1.059	6.22
1.212	19.80	1.048	5.00
1.198	18.67	1.037	3.96
1.184	17.54	1.026	2.83
1.170	16.41	1.015	1.70
1.157	15.28	1.005	0.57

Use. Potassa, in solid form, is employed as a powerful escharotic, and for this purpose its solution may be boiled down in a clean iron vessel, and poured into moulds. Both in solid form and in solution, it is one of the most valuable agents in the laboratory for scientific research, from its powerful basic qualities. In solution it is largely employed, for the decomposition of fatty bodies in the manufacture of soap, but its use for this purpose is at present limited by the greater cheapness of soda.

Salts. Potassa is the most powerful base, neutralizing strong acids perfectly, while salts of feeble acids have alkaline reaction. The salts are colorless, unless the acid be colored; fixed in the fire, unless the acid be decomposable; generally soluble in water. When the solutions are not too dilute, they give a precipitate with bichloride of platinum, and with carbazotic acid, yellow; with excess of tartaric acid, perchloric acid, and fluosilicic acid, white, the latter almost transparent; with sulphate of alumina and a little sulphuric acid, white crystals of alum. In alcohol the double salt of platinum is insoluble.

b. Peroxide of P. KO_2 . It forms by burning potassium in the air, or by continued ignition of caustic potassa in the air. It is orange-yellow, fusible, and oxidizes metals and other combustibles by the aid of heat. There is probably a suboxide, K_2O .

3. Sulphur. *a. Sulphuret of P.*, KS , is formed when sulphate of potassa is ignited with charcoal or in hydrogen gas. It is red, crystalline, soluble in water. The solution may also be made by dividing a solution of potassa into two equal parts, passing sulphohydrogen through one to saturation, apart from the air, boiling it to expel the excess of gas, and then mixing the two together. It is a colorless, strongly alkaline liquid, which evolves sulphohydrogen with muriatic acid, without deposition of sulphur. It is a strong sulpho-base, forming many sulphosalts, of which three now follow, and the others will be found under tellurium, arsenic, &c.

Sulphydrate of P., or *Sulphohydrate of Sulphuret of P.*, KS , HS , is formed dry by passing sulphohydrogen over carbonate of potassa, at low redness, until effervescing carbonic acid ceases to rise; or in solution by passing the same gas through a potassa solution to saturation, apart from the air, and boiling to expel the excess of gas. If the saturation be performed in strong lye in a retort and an atmosphere of hydrogen, and it be evaporated to a syrup in the same, it forms large, colorless

POTASSIUM.

crystals of the salt. The solution changes in the air, first to penta-sulphuret and potassa, and then to hyposulphite of potassa.

Sulphonitrite of P., KS , NS_3 , is obtained as a deep red solution by dissolving tersulphuret of nitrogen in a solution of potassa; exposure to air resolves it into dithionate of potassa and ammonia.

Sulphocarbonate of P., KS , CS_2 , is formed by adding bisulphuret of carbon to an alcoholic solution of sulphuret of potassium, as long as it dissolves; the liquid divides into three strata, the lowest being the salt in question, the middle the excess of sulphocarbon, and the upper a persulphuret of potassium, with sulphocarbon. Evaporated to a syrup, it yields a yellow, crystalline salt, very soluble in water, scarcely in alcohol.

b. Bisulphuret of P., KS_2 , is formed by exposing the alcoholic solution of sulphhydrate of potassium to the air, until it becomes cloudy from the formation of dithionite, and then evaporating in vacuo. It may be obtained impure by heating a mixture of $8\frac{3}{4}$ pts. carbonate of potassa with $3\frac{1}{2}$ pts. sulphur. Its solution also oxidizes into dithionite.

c. Tersulphuret of P., KS_3 , is formed impure by heating $8\frac{3}{4}$ pts. sulphur with 5 pts. of sulphur, or purer by passing sulphuret of carbon in vapor over ignited carbonate of potassa, as long as a fixed gas rises. Its solution forms the dithionite, and sulphur precipitates.

d. Quadrisulphuret of P., KS_4 , is formed by passing vapor of sulphocarbon over ignited sulphate of potassa. It changes in the air like *c*, depositing more sulphur.

e. 5-fold Sulphuret of P., KS_5 , is formed impure, by heating gradually to ignition nearly equal weights of sulphur and carbonate of potassa; or more exactly, 4 equivs. carbonate ($69.11 \times 4 = 276.44$) and 16 equivs. sulphur ($16 \times 16 = 256$); $4(\text{KO}, \text{CO}_2) + 16\text{S} = 3\text{KS}_5 + \text{K}_2\text{O}, \text{SO}_3 + 4\text{CO}_2$. By gently heating the carbonate with an equal amount of sulphur, it forms the pentasulphuret and dithionite; $3\text{KO} + 12\text{S} = 2\text{KS}_5 + \text{K}_2\text{O}, \text{S}_2\text{O}_2$. A solution of this sulphuret is also made by boiling caustic potassa for a short, or the carbonate for a longer time, with excess of sulphur; the excess of sulphur separates on cooling. The solution changes in the air like *d*, depositing more sulphur. Acids liberate sulphohydrogen, precipitate sulphur, and form a salt with potassa. It precipitates metallic solutions, like all the preceding sulphurets, and forms a convenient qualitative test for the metals.

f. By passing sulphohydrogen over ignited sulphate of potassa as long as water forms, a peculiar sulphuret is formed, composed of K_2S_7 . By passing the same gas through an ignited mixture of quadrisulphuret, *d*, and sulphur, another compound forms, K_2S_9 . Berzelius regards them as definite compounds, and if so, we have potassium uniting with 1, 2, 3, $3\frac{1}{2}$, 4, $4\frac{1}{2}$, and 5 equivs. sulphur.

4. Nitrogen. *a. Amide of P.*, K , NH_2 . Potassium is gently heated in ammoniacal gas, until after passing through blue and green, it becomes olive-green, when the operation is discontinued; $\text{K} + \text{NH}_3 = \text{K}, \text{NH}_2 + \text{H}$. It decomposes with water, acids, and alcohol into potassa and ammonia; $\text{K}, \text{NH}_2 + \text{HO} = \text{KO}$

+ NH_3 . By ignition to low redness, apart from the air, it evolves ammonia and becomes *b.*; $3(\text{K}, \text{NH}_2) = 3\text{KN} + 2\text{NH}_3$. *b. Nitropotassium*, K_3N , is greenish black, decomposing by a high heat into potassium and nitrogen, and by water into ammonia and potassa, $\text{K}_3\text{N} + 3\text{H}_2\text{O} = 3\text{KO} + \text{NH}_3$.

5. *Phosphuret of P.* is formed by heating potassium and phosphorus in a thin glass flask, in an atmosphere of dry hydrogen, passing the gas through until the excess of phosphorus has sublimed. Copper-red, with metallic lustre, decomposing violently with water.—A carburet of potassium seems to form in the preparation of potassium. Silicium and potassium unite by heat, and the vapor of potassium decomposes silica.

6. *Alloys.* These are readily obtained by strongly igniting a mixture of cream of tartar with the finely powdered metal, as antimony, lead, &c.; but they may also be formed by direct fusion of the two metals. They generally decompose with water into potassa and the other metal, in a spongy state. Mercury, with only $1\frac{1}{2}$ pr. ct. potassium, forms a crystalline amalgam; with less than that quantity, a fluid. Potassium combines readily with arsenic, antimony, bismuth, tin, lead, and zinc; has a strong affinity for platinum, and combines at a high temperature with iron.

HALOID SALTS.

1. *Chlorine. Chloride of P.*, KCl . Potassium spontaneously burns in chlorine, and even decomposes chlorohydric acid, evolving hydrogen; but the salt is either made by solution of potassa or its carbonate in chlorohydric acid, or it is obtained as a residuary product in chemical processes. Taste, form, and other properties like common salt, but rather more volatile and soluble, 1 pt. dissolving in 2.85 pts. water at 60° ; somewhat soluble in alcohol. It is a strong chlorobase, forming double salts with many metallic chlorides. *Chloriodate of Chloride of P.*, KCl, ICl_3 , is obtained by the action of chlorine on a solution of iodine and chloride of potassium, or on a saturated solution of iodide of potassium, by solution of hydriodate and chlorate of potassa in hot, or of iodine and chlorate in warm muriatic acid. The cooling solutions deposit crystals, golden, lustrous prisms, smelling and acting on the skin like chloride of iodine; soluble in water, in which they change into muriate and iodate of potassa, with other products. *Sulphate of Chloride of P.*, KCl, SO_3 , is formed by passing vapor of dry sulphuric acid into the powdered salt. *Bichromate of Chloride of P.*, $\text{KCl}, 2\text{CrO}_3$, is obtained by boiling bichromate of potassa, for a short time, with an excess of muriatic acid; on cooling it separates as orange-red prisms, permanent in air, decomposing in water into its original constituents.

2. *Bromine. Bromide of P.*, KBr . The two elements unite powerfully. The salt is made impure from the mother liquor of some salines, by crystallization; purer by neutralizing potassa with bromhydric acid; by decomposing a solution of bromide of iron by a due proportion of carbonate of potassa; by dissolving bromine in potassa until a color ensues, evaporating and igniting, dissolving in water, and

saturating with bromhydric acid; by passing an excess of sulphohydrogen through the same solution of bromine in potassa, expelling the excess by boiling, filtering off sulphur, and neutralizing an excess of bromhydric acid or potassa, by potassa or the acid, as the case may require. Colorless, regular crystals, of a pungent, saline taste, quite soluble in water, slightly in alcohol, fusible without decomposition; decomposed by chlorine with heat, changed by fusion with chlorate of potassa into bromate of potassa. A bibromide is said, by Löwig, to be formed when bromide is added to a solution of 1 pt. of bromide in 6 pts. water, and a terbromide when bromine is added to equal pts. of bromide and water.

3. *Iodine. a. Iodide of P.* Besides the methods given for bromide, which serve for iodide, the following for iodide may be followed: 1. A mixture of iodine, zinc, and water, forming iodide of zinc, is exactly precipitated by carbonate of potassa. 2. To 1 pt. iron filings in 10 or 20 pts. water, add 2—3 pts. iodine gradually, filter as soon as the liquid is colorless, precipitate by caustic potassa while boiling, filter, and evaporate. 3. Add an alcoholic or aqueous solution of sulphuret of potassium to a tincture of iodine until the latter becomes colorless, filter, and evaporate. 4. Dissolve sulphuret of barium in water, add iodine as long as it dissolves, filter, precipitate by carbonate of potassa, filter again, and evaporate. 5. Add 3 pts. iodine to 4 pts. of a fresh potassa lye (of 1.333), until the solution has a brownish yellow color, pour the whole solution and sediment into a capsule, evaporate to dryness, grind to a fine powder, mix with $\frac{1}{2}$ its weight of fine charcoal, transfer it by small portions into an iron crucible at a red heat, heat for $\frac{1}{4}$ hour when fully charged, empty the contents into an iron vessel, and transfer the mass, when cold, into a porcelain capsule, pour over it an equal weight of water, assisting solution by warmth, filter, and evaporate slowly, to crystallize. The mother liquor may be evaporated several times to crystallize, and finally treated with spirit of wine (80 pr. ct.), which leaves carbonate of potassa.

Prop. Cryst. regular cubes and 8-hedra; fusible; volatilizing below redness in the air; deliquescent in very moist air, when pure; soluble in 0.735 pts. water at $54\frac{1}{2}^\circ$, in 0.709 at 61° , in 5.5 pts. alcohol (of 0.85) at $54\frac{1}{2}^\circ$, in 40 pts. absolute alcohol. Form. KI , containing 76.3 pr. ct. iodine. Chlorine decomposes it into chloride of potassium and iodine, but more chlorine forms the chloriodate of chloride of potassium; it is decomposed by evaporation with nitric acid; by fusion with chlorate of potassa, it forms iodate of potassa.

b. Bimiodide of P. 100 pts. iodide in 400 pts. water, dissolve $76\frac{1}{2}$ pts. iodine, to form this compound. 100 pts. iodide in 200 water, dissolve 153 pts. iodine, to form a teriodide.

c. Arsenite of Iodide of P., $\text{KI} + 3\text{AsO}_3$. A white salt, formed by boiling the iodide with arsenious acid, or by adding iodine to a solution of neutral arsenite of potassa.

4. *Fluorine. a. Neutral Fluoride of P.*, KF . Obtained by nearly saturating fluohydric acid with carbonate of potassa, and evaporating at about 100° , to crystallize, forms cubes, very

deliquescent, of alkaline reaction; by mixing a strong solution with alcohol, it crystallizes with 4 HO.

b. KF + HF. Bifluoride is obtained by adding fluohydric acid to the preceding, and evaporating. By heating to ignition it becomes *a*, by loss of acid; is soluble in water, scarcely in fluohydric acid.

c. Borofluoride of P., KF, BF_3 , is precipitated by dropping borofluohydric acid into a solution of fluoride of potassium; it is transparent and gelatinous, but when dry a white, starchy powder, soluble in 70 pts. cold, and much less hot water, slightly in alcohol, from both which it crystallizes; soluble in ammonia and in caustic and carbonated potassa and soda, unaltered.

d. Silicofluoride of P., $3 \text{KF}, 2 \text{SiF}_3$, obtained by dropping silicofluohydric acid into a salt of potassa, forms a translucent precipitate, becoming a white powder on filtering and drying; very similar to the borofluoride in its behavior to water, alkali, and by heat, but it is decomposed by ammonia.

OXYSALTS.

1. *Sulphur. a. Sulphate of P.* It is obtained by a direct union of acid and base, or as a secondary product in many chemical operations. Colorless, right rhombic crystals, decomposing by heat, and fusing at a red heat; soluble in 12 pts. water at 32° , and uniformly more by increasing heat; insoluble in caustic lye of spec. grav. 1.35. Form. KO, SO_3 , containing 54.12 pr. ct. potassa. By ignition with charcoal it forms sulphuret of potassium; most acids remove half of the potassa, and leave—

b. Bisulphate of P. A secondary product in extracting nitric acid from saltpeter, by oil of vitriol. The dry salt, $\text{KO}, 2 \text{SO}_3$, is made by adding 1 equiv. oil of vitriol to a solution of 1 equiv. of the neutral salt, *a*., and evaporating. The hydrated salt, $\text{KO}, \text{SO}_3 + \text{HO}, \text{SO}_3$, made by adding more oil of vitriol, crystallizes in rhombs, fuses at $4-500^\circ$, forming a clear liquid, from which vapors of dry sulphuric acid escape; soluble in $\frac{1}{2}$ pt. boiling water; if much water be used, the neutral salt, *a*., crystallizes out.

c. Nitrosulphate of P. is obtained by cooling a solution of *a*. in warm and strong nitric acid; form. $2 (\text{KO}, \text{SO}_3) + \text{HO}, \text{NO}_5$. A similar solution in warm, syrupy, phosphoric acid, yields an analogous salt, $2 (\text{KO}, \text{SO}_3) + 3 \text{HO}, \text{PO}_5$. Both salts may be viewed as phosphate and nitrate of potassa, with the hydrated bisulphate.

d. Sulphite of P., KO, SO_2 , is formed by passing sulphurous acid gas into aqueous carbonate of potassa, until carbonic acid ceases to escape, and evaporating. It changes readily to sulphate, and reduces to metal the oxides of mercury, silver, gold, and to a lower oxide those of copper, iron, lead, and manganese; precipitable by baryta or lime-water. The bisulphite crystallizes more readily. The sulphite, with a little potassa, absorbs nitric oxide gas, forming a neutral, crystallizable salt, $\text{KO}, \text{SO}_2, \text{NO}_2$, which by heat, by all acids, and many metallic oxides and salts, is resolved into 80 pr. ct. sulphate of potassa and 20 pr. ct. nitrous oxide gas.

e. Dithionate of P. Hyposulphate, $\text{KO}, \text{S}_2\text{O}_5$, is obtained by precipitating sulphate of potassa by dithionate of baryta, filtering, and evaporating. The crystals are permanent in air, soluble in $16\frac{1}{2}$ pts. water at 60° , and in 1.58 boiling water; insoluble in alcohol.

f. Dithionite of P. $3 (\text{KO}, \text{S}_2\text{O}_2) + \text{HO}$. (See mode of making the same salt of soda.) It forms clear, inodorous, 4-sided prisms, deliquescent, oxidizing in the air, and resolved by heat into 1 equiv. 5-sulphuret of potassium, and 3 equivs. sulphate of potassa.

g. Trithionate of P., $\text{KO}, \text{S}_3\text{O}_6$, obtained by digesting a saturated solution of bisulphite of potassa with flowers of sulphur for 3 or 4 days (without ebullition), until the yellow coloring disappears; the hot liquid deposits crystals of trithionate, with a little sulphate, and by solution in a little warm water, filtering, and cooling, the salt is obtained pure.

2. *Nitrogen. a. Nitrate of P.* Nitre, Saltpeter. Found native in some soils, especially in tropical climates, or obtained from nitrate of lime, similarly found native, by potash. It is from these nitrates that nitric acid and other compounds of nitrogen are obtained. Small quantities of nitric acid are doubtless formed by the direct union of nitrogen and oxygen in the air, by electrical discharges; for it has been found in the air, and has been made artificially in a similar manner. It is also formed when ammonia gas is passed, with oxygen or air, through an ignited tube, or over heated oxide of iron or of manganese; or when milk of lime and a little ammonia are frequently shaken in a closed flask full of air, for some 6 weeks in summer. In these cases nitric acid, or oxide of nitrogen, or nitrate of ammonia is formed, and the oxide oxidizes to nitric acid. Some soils containing nitrogenous organic matter, together with lime, potassa, or other alkaline base, slowly generate nitrates; and it is probable that, by the putrefaction of the organic matter, ammonia is first generated, and then nitric acid, according to the above observations. It is also probable that in these soils the nitrogen of the air assists in forming nitric acid, for it is found in situations (chalk formation) where there is but little organic matter.

Prep. Saltpeter is prepared by leaching the natural soils containing it, previously adding some carbonate of potassa to decompose nitrates of lime and magnesia; or it is leached from artificial saltpeter-beds. These beds are made by mixing nitrogenous organic matter (after putrefaction has commenced) with mortar of decayed buildings, soil containing carbonate of lime, &c., into heaps, and moistening them from time to time with urine, &c. When the lye is partly evaporated, the remaining nitrates of lime and magnesia are thrown down by carbonate of potassa, filtered or drawn off, and evaporated, to crystallize out the chlorides, and further evaporated and cooled. Crude saltpeter crystallizes out. By repeated crystallization it is refined or rendered purer, but still retains chloride. It may be obtained absolutely pure by dissolving the refined salt in boiling water to saturation, stirring it as it cools to produce a crystalline powder, and washing this with a saturated solution of pure saltpeter until it no longer tests of chloride by

nitrate of silver. It may be kept in this state of powder, or fused and cast into blocks.

Prop. Saltpeter is dimorphous, crystallizing in two forms, the right rhombic, prismatic, which is the usual form, and the hexagonal, an obtuse rhomb, the last the same as soda-saltpeter. It is soluble in 13·32 pts. water at 32°, in 3·4 at 64°, in 1·34 at 113°, and in 0·424 at 207°; the presence of nitrate of lime or common salt is said to make it more soluble; it is soluble in 100 pts. spirit of wine. It fuses below a red heat without losing oxygen, but by increase of heat pure oxygen passes off, leaving nitrite of potassa, and by still further heat nitrogen and oxygen pass off, leaving oxide and peroxide of potassium. Mixed with charcoal, sulphur, iron, or other combustible, it deflagrates when thrown on glowing coals, and even oxidizes platinum when fused in it. (See GUNPOWDER.) Form. KO, NO_3 , containing 46·6 pr. ct. $\text{KO} + 53·4$ pr. ct. NO_3 .

b. Nitrite of P., KO, NO_2 , obtained by heating saltpeter until a portion of oxygen is evolved, dissolving the residue in water, evaporating to crystallize out saltpeter, and still further to obtain the nitrite. It is a neutral, deliquescent salt.

3. Phosphorus. a. Phosphate of P. When common phosphoric acid is neutralized with carbonate of potassa until it has an alkaline reaction, and evaporated, the neutral salt, $2 \text{KO}, \text{PO}_5 + \text{HO}$, crystallizes. When this salt is heated to ignition, HO passes off, and the dry c phosphate (not the b phosphate) remains, soluble in water, and precipitating yellow, basic c phosphate, with nitrate of silver. If this salt be mixed with as much more acid as it contains, and evaporated, large crystals of the acid salt are formed, or biphosphate, $\text{KO}, \text{PO}_5 + 2 \text{HO}$. It loses its water by ignition, and becomes b phosphate, with anhydrous phosphoric acid as its pairing or conjugate. (*Berzelius.*) This is usually called neutral a phosphate. A basic phosphate, $3 \text{KO}, \text{PO}_5$ is formed by adding potassa to any of the above, and removing the excess of alkali by alcohol.

b. Phosphite of P., $2 \text{KO}, \text{PO}_3$, is deliquescent, insoluble in alcohol. *c. Hypophosphite of P.*, KO, PO , is obtained by boiling phosphorus with potassa, when water is decomposed and phosphuretted hydrogen liberated. By its solubility in alcohol, it is freed from any of the foregoing salts. *d. Phosphoric oxide Potassa*, $\text{KO}, \text{P}_2\text{O}_5$, is obtained by pouring potassa over oxide of phosphorus, and when it becomes black, pouring it off again.

4. Halogens. a. Perchlorate of P., KO, ClO_7 . It is obtained by heating the chlorate *b* to fusion, and maintaining it at the point where oxygen passes off, until it has lost $8-8\frac{1}{2}$ pr. ct. of its weight of gas. It then consists of about 65 pr. ct. perchlorate and 35 of chloride of potassium; the former, by its inferior solubility, is separated from the latter by crystallization. It is soluble in 65 pts. water at 59°, and in much less hot water; insoluble in alcohol; it detonates slightly with sulphur, and deflagrates less with ignited coals than its content of oxygen would indicate.

b. Chlorate of P. Oxymuriate of potash. *Prep.* 1. Obtained by passing chlorine into carbonated or caustic potassa as long as it is

absorbed, whereby chloride of potassium and chlorate of potassa result, and are separated by crystallization. To prevent the stoppage of the end of the tube in the solution, a small funnel may be attached to it by a caoutchouc tube. 2. Mix 1 pt. carbonate of potassa with 2 pts. dry-slacked lime (hydrate of lime), pass chlorine through to saturation, dissolve in boiling water, filter, and let the chlorate crystallize out. In this process chlorate of potassa and chloride of calcium are chiefly formed, and the latter being very soluble, the former is more easily purified. 3. Evaporate a solution of bleaching salt (old and spoiled salt is good) to dryness, to convert the hypochlorite into chlorate of lime, extract with water, precipitate boiling with carbonate of potassa, filter hot, and let chlorate of potassa crystallize out. Recrystallization in all these processes purifies the chlorate.

Prop. KO, ClO_3 , containing 61·5 pr. ct. chloric acid. It generally crystallizes in flat plates, is soluble in 30 pts. water at 32°, in 16·7 at 59°, in 8·33 at 95, in 5·26 at 120°, in 1·67 at 219°; soluble at 61° in 120 pts. alcohol (of 83 pr. ct.); fuses by heat, evolves oxygen with effervescence, but requires ignition to drive off all the oxygen, which is 39·16 pr. ct. of the salt; by previously mixing it with an equal bulk of binoxide of manganese, it parts with all its oxygen at a much lower temperature, and without puffing. From its large content of oxygen and the readiness with which it yields the gas, it is used for making detonating mixtures with combustibles, as friction matches, percussion caps, some colored fires in fire-works, and in obtaining oxygen. A few grains of flowers of sulphur and of this salt rubbed in a mortar, produce a succession of crackling deflagrations. It is dangerous to bring it in contact with phosphorus, as it explodes with slight friction. The fusing salt changes litharge to binoxide of lead, and fused with potassa and binoxide of manganese, forms green manganate of potassa. Its solution is a convenient mean of oxidizing lower oxides in solution, especially by heat; and if sulphuric or nitric acid be added, it oxidizes still more powerfully.

c. Chlorite of P., KO, ClO_2 , obtained by saturating potassa slowly with chlorous acid until it begins to be reddish, when it is evaporated rapidly in a water bath; it has no permanency.

d. Hypochlorite of P., KO, ClO . Obtained like *c*, with hypochlorous acid, or by passing chlorine into a solution of potassa for a short time. If passed into carbonate of potassa until carbonic acid ceases to escape, the solution contains 2 equivs. chloride of potassium and 1 equiv. bi-hypochlorite of potassa; and by neutralizing with potassa until the yellow color disappears, the neutral salt is formed. It cannot be obtained in a dry state without decomposition.

e. Bromate of P., KO, BrO_3 . Obtained by saturating potassa or its carbonate with bromine, forming bromide and bromate, and crystallizing (like *b*). By fusion it gives off oxygen, and leaves bromide of potassium.

f. Periodate of P., KO, IO_5 . If chlorine be passed through a solution of iodate, *g*., containing potassa, the periodate separates in

small white crystals, difficultly soluble in water, yielding 27.14 pr. ct. oxygen by heat. If potassa be added to a solution of the periodate and evaporated, a subiodate crystallizes, composed of $2 \text{ KO}, \text{ IO}_5$.

g. Iodate of P. $\text{KO}, \text{ IO}_5$. Obtained by adding iodine to potassa lye, until the brown color begins to be permanent ($6 \text{ KO} + 6 \text{ I} = \text{KO}, \text{ IO}_5 + 5 \text{ KI}$), evaporating to dryness, and extracting the iodide by alcohol of 0.81; or by fusing 1 pt. iodide of potassium in a crucible, and when cooled until it is half liquid, adding $1\frac{1}{2}$ pts. chlorate of potassa; purified by crystallization. It is soluble in 13 pts. water at 57° , more so in water containing iodide; insoluble in alcohol. By adding muriatic acid and then alcohol to a solution of iodate, a biniodate, $\text{KO}, 2 \text{ IO}_5$, separates, crystallizable, soluble in 75 pts. water at 59° , not in alcohol. By heating a solution of iodate with a large excess of dilute sulphuric acid, and leaving it to evaporate at 77° in the air, a triniodate, $\text{KO}, 3 \text{ IO}_5$, crystallizes, soluble in 25 pts. water at 59° .

5. Carbonates of P. a. Neutral. Syn. Pearl-ash, Potash, Mild alkali, Fixed vegetable alkali, Salt of Tartar. Common potash and pearl-ash are obtained from the ashes of plants, and when purified, the salt is termed Salt of Tartar. It is sometimes made by heating salts of potassa with vegetable acids, or by deflagrating nitre and charcoal.

Potash, Pearl-ash. See the article ASHES for their composition. The ashes, sifted from the charcoal, are moistened and pressed into lixiviating tubs, on a false bottom perforated with holes and covered with straw. These are conveniently placed in two rows, one above the other, and the liquor of the upper one run through the lower, and then into the receiving cisterns or wells. After water has once passed through, fresh water is added, and this weaker liquor is passed through fresh ashes. Water is thus passed through all until the ashes are spent, and each time becomes fully charged by being passed through fresh ashes. The dense liquors are then evaporated in an iron pan, fresh liquor being constantly added, until a large quantity collects as a syrupy liquid, which congeals rapidly on cooling in a sample taken out. It is then evaporated to dryness at a moderate heat, and the solid mass finally broken out by chisels. This black *crude ash* is sometimes brought to market. To whiten it, it is calcined in a reverberatory furnace, similar to those for making red lead, first at a red heat to expel water, and then at a higher heat to burn off carbonaceous matter. The calcined potash consists of a portion soluble in water, containing carbonate, sulphate, muriate, and silicate of potassa (sometimes with soda), usually with smaller quantities of manganate and phosphate of potassa, sulphuret of potassium, and organic matter; and a portion insoluble in water, containing silica, silicate, phosphate, and carbonate of lime and of magnesia, oxides of iron and manganese, alumina, sand, and charcoal. In the American manufacture, the bottoms of the tubs are covered with brushwood to the depth of 6–8 inches, then with several inches of straw, and the ashes placed on the latter. The lye is evaporated as usual in iron pans, to make brown salts, which are

fused in another iron vessel for an hour or two, when they form the Potash of commerce. This redissolved in water, and the solution evaporated to dryness and calcined in a reverberatory, constitutes Pearl-ash. A stronger lye is obtained by mixing a little lime with the ashes.

The value of Pot and Pearl-ash is ascertained by the processes of ALKALIMETRY. The process by determining the amount of carbonic acid, is not to be relied on either for soda-ash or for potash, because both caustic potassa and soda are contained in them.

A purer carbonate is made by calcining cream of tartar (bitartrate of potassa), which destroys the tartaric acid, and forms carbonate of potassa. But it may be also obtained from pearl-ash by solution in a small amount of water, filtration, evaporation until a pellicle forms on the surface, and cooling, to separate the sulphate and most of the chloride by crystallization. The mother liquor yields a purer carbonate, which may be further purified by a repetition of the process; but the carbonate will still retain some chloride.

Prop. Pure carbonate of potassa is white, alkaline to taste and test, fusible at a red and volatile at a white heat, deliquescent in the air, forming an oily liquid, soluble in 1.05 pts. water at $37\frac{1}{2}^\circ$, in 0.9 at 55° , in 0.747 at 79° , and 0.49 at 158° . The following table shows the percentage content of dry salt, at different gravities:—

Sp. grav.	Pr. ct.	Sp. grav.	Pr. ct.
1.475	40	1.170	15
1.409	35	1.111	10
1.353	30	1.066	5
1.302	25	1.035	3
1.234	20	1.009	1

Dry, pure carbonate contains 68.16 pr. ct. potassa + 31.84 carbonic acid. It sometimes crystallizes from strong solutions with 2 HO.

b. Sesquicarbonate of P. It crystallizes from mixing *a.* and *c.* together.

c. Bicarbonate of P. $\text{KO}, 2 \text{ CO}_2 + \text{HO}$. Formed by passing carbonic acid through a concentrated solution of *a.*, or over *a.* moistened. It forms rhombic crystals of a feeble, alkaline reaction, permanent in air when dry, soluble in 4 pts. cold, in 0.83 pts. boiling water, in 1200 pts. alcohol.

6. Borates of P. a. Neutral. 61.8 pts. (1 eq.) cryst. boracic acid is fused with 69.1 pts. (1 eq.) dry carbonate of potassa. It is fusible, caustic, alkaline, decomposing by the carbonic acid of the air into baborate. *b. Baborate*, $\text{KO}, 2 \text{ BO}_3 + 5 \text{ HO}$, is made by saturating carbonate of potassa boiling, with boracic acid, adding potassa until it is alkaline, and crystallizing. Alkaline, very soluble, fusible. Crystals of a terborate, *c.*, $\text{KO}, 3 \text{ BO}_3 + 8 \text{ HO}$, sometimes form in the liquid *b.* *d. Sexborate of P.*, $\text{KO}, 6 \text{ BO}_3 + 10 \text{ HO}$, crystallizes from the solution made neutral by acid. Permanent in air, with feeble acid reaction, slightly soluble in cold, readily in hot water.

7. Silicates of P. These important compounds form the basis of various kinds of glass, but silicic acid has the power of fusing in so many proportions with potassa, that its definite compounds are little known. 1 equiv. silica heated with carbonate of potassa, will

POTATO, IRISH.

expel no more than 3 equivs. carbonic acid, forming soluble glass, $3\text{ KO}, \text{SiO}_3$. In the mineral kingdom there are many determinate degrees of saturation, but they are contained in double silicates, as in feldspar, labradorite, &c. See *Chemical Relations of GLASS*.

POTATO, IRISH. The tubers of the *Solanum tuberosum*. The following analyses show their composition:—

	Hardy.	Henry.
Water.....	74.00	73.12
Starch.....	12.50	13.30
Woody fibre.....	7.50	6.79
Gluten, albumen.....	1.00 (Albumen)	0.92
Sugar.....	2.40	3.30
Fatty matter.....	0.60	1.12
Salts.....	2.00	1.40
Volatile poisonous matter —		0.05

Payen and Persoz found **DIASTASE** in the neighbourhood of the bud, and Otto discovered **SOLANIN** in the bud itself. To the presence of the latter is attributed the ill effects from the use of germinated potatoes, as food.

The ashes, as analyzed by Prof. J. W. Hardy, of Va., contain—

	Roots.	Tops.
Silica.....	6.8	12.5
Potassa.....	52.5	45.3
Soda.....	0.5	0.7
Lime.....	2.0	2.5
Magnesia.....	4.5	2.0
Oxide of iron and alumina..	1.0	6.0
Carbonic acid.....	12.5	12.0
Phosphoric acid.....	12.5	9.6
Sulphuric acid.....	7.0	9.0

Vogel found 17.5 pr. ct. of insoluble, and 82.5 pr. ct. of soluble salts, but no silica. (*Ann. de Chem. et Pharm.* xlix. 245.)

Among the products generated by the fermentation of potatoes are **ALCOHOL**, **FOUSEL OIL** (see **AMYL**), and **BUTYRIC ACID**.

Potato flour is sold as arrow-root. Its admixture with wheat flour, in limited proportion, improves the quality of bread, renders it lighter, prevents crumbling, and enables it to retain sweetness and moisture for a long time.

Kemp's investigations as to the changes accruing in the tuber, while diseased with the "potato blight," are recorded in Vol. v. *Chem. Gaz.*, p. 69. His conclusions are—

1. "That the morbid affection consists of a premature tendency to assume the organic changes which are consentaneous with, and essential to the process of germination.

2. "That the presence of fungi and insects do not account for these changes, and cannot therefore be considered as their exciting cause.

3. "That the cause must be sought for amongst those agents which induce the process of germination in seeds and tubers.

4. "That further analytic investigation is necessary, in order to elicit the mode of action of such agents, as well as the peculiar conditions under which their agency becomes developed."

POTATO, SWEET. (Yam.) The tuberous, nutritious root of the *Convolvulus batatas*. Hardy's analyses of its ashes give the following result:—

PROTEIN.

	Root.	Tops.
Potassa.....	54.6	46.8
Soda.....	0.8	0.6
Silica.....	5.4	10.5
Lime.....	3.5	4.0
Magnesia.....	4.3	3.4
Oxides of iron and alumina...	1.5	7.0
Phosphoric acid.....	15.5	11.0
Sulphuric ".....	8.4	8.7
Carbonic ".....	6.0	8.0

POTSTONE. See **TALC**.

POUDRETTE. *Agric.* A manure made by separating the liquid from the solid portion of animal excrements, and drying the latter by exposure to air. The objection to this powerful fertilizing agent, on account of the disagreeable taste which it imparts to the growing plant, is obviated by previous disinfection. This is accomplished by the use of a mixture of neutral protosulphate of iron, gypsum, and charcoal dust, which effectually checks all offensive emanations, and at the same time fixes the ammonia as sulphate. Charred sawdust and tan are sometimes substituted for the coal-dust; but a still better material than all is the "animalized black," prepared by calcining peat or river-mire. The highly disinfected powder thus made, completely deodorizes fæcal matters, by absorbing and confining the volatile and odorant products of decomposition as fast as they are generated. See *Dumas*, "The Farmer's Guide," vol. viii.

PRASE. See **QUARTZ**.

PRASEOLITE. *Min.* Prismatic. $H. = 3.5$. $G. = 2.754$. Green, with feeble lustre. Yields water, fuses with difficulty on thin edges to a bluish green glass, and with the fluxes shows the presence of silica and iron. Form. $3\text{ MgO}, \text{SiO}_3 + 2(\text{Al}_2\text{O}_3, \text{SiO}_3) + 3\text{ HO}$. From Brevig, Norway.

PRASILITE. A variety of **CHLORITE**.

PREHNITE. *Min.* Cryst. Right rhombic, with distinct basal cleavage; also globular and other imitative forms, and pseudomorphs of analcime, &c. $H. = 6 - 6.5$. $G. = 2.8 - 2.95$. Green, generally light; vitreous; subtransparent, translucent; somewhat brittle, with uneven fracture. Behaves like the zeolites. After strong ignition, it dissolves readily in dilute muriatic acid, leaving gelatinous silica. Form. $2\text{ CaO}, \text{SiO}_3 + \text{R}_2\text{O}_3, \text{SiO}_3 + \text{HO}$, in which $\text{R} = \text{Fe}$ and Al . Found in granite, gneiss, and trap rocks, in many localities.

PRINCE'S METAL. See **ALLOYS**.

PROTEIN. *Chem. Physiol.* Formula $\text{C}_{40}\text{H}_{31}\text{N}_5\text{O}_{12}$ (*Mulder*), $\text{C}_{48}\text{H}_{36}\text{N}_6\text{O}_{14}$ (*Liebig*). Derives its name from *πρωτεω*, I am first, because Mulder, its discoverer, regards it as the basis of **ALBUMEN**, **FIBRIN**, and **CASEIN**, whether of animal or vegetable origin.

Prep. Either of the three above-named substances that may be selected, is to be freed of extractive, fatty, and soluble matters by successive washings in water, alcohol, and ether, and then treated with dilute HCl acid for the removal of phosphate of lime and insoluble salts. The residue is treated with moderately strong potassa or soda ley at 140° , which after a time converts the sulphur and phosphorus into phosphate and sulphuret. The filtered solution being now treated with acetic acid, in

very slight excess, yields a gelatinous precipitate of protein. After being thoroughly washed upon a filter, it is in the form of grayish flocculae, which contract, on drying, into a hard, brittle, yellowish mass.

Prop. Forms an inodorous, tasteless, amber-colored, hygrometric powder, which burns on exposure to air without leaving ash. Is insoluble in water, alcohol, ether, and the essential oils. Combines with both acids and bases. Is precipitable from any of its acid solutions by ferro- and ferrid-cyanide of potassium, by tannin, anhydrous alcohol, various metallic salts, and by the alkalis.

Action of Potassa. When protein is boiled with a concentrated solution of potassa until ammonia ceases to be given off, the resultant liquor will be found to contain carbonate and formate of potassa, with three new products.

1. *Erythrophotid.* $C_{13}H_8NO_5$ (Mulder). A reddish brown, deliquescent extract, soluble in water and boiling alcohol, and precipitable from its aqueous solution by the metallic salts and tannin, of a rose-red color.

2. *Protide.* $C_{13}H_9NO_4$ (Mulder). A straw-yellow, amorphous solid. Is soluble in water and alcohol without color. Is precipitated by the basic acetate of lead.

3. *Leucin.* $C_{12}H_{12}NO_4$ (Mulder). Crystallizes in brilliant, inodorous, tasteless scales, of less spec. grav. than water, which sublime without change at 340° , and are soluble in water and alcohol, but not in ether. Leucin is also formed by the action of nitric acid upon GELATIN, and of sulphuric acid upon flesh. It combines with nitric acid, and forms *nitro-leucic acid*.

Action of Sulphuric Acid. Boiling, dilute sulphuric acid produces a beautiful purple coloring. When protein is treated with strong sulphuric acid, it swells and gelatinizes, and on the addition of cold water contracts without dissolving. This new acid compound is called—

Sulphoproteic Acid, $C_{40}H_{31}N_5O_{12}, SO_3$. When dried, it is a yellow mass, insoluble in water, alcohol, and ether, but soluble in ammonia, and potassa, and capable of union with bases.

If the sulphuric is diluted and added to an acetic solution of protein, Mulder's *Sulpho-bi-proteic Acid* ($C_{80}H_{62}N_{10}O_{24} + H_2O_2 + SO_3$) is formed. It is in flocculae when fresh, but becomes white and readily pulverizable on drying. With the alkalis it forms solutions from which many of the metallic salts precipitate insoluble compounds.

Action of Chlorine. When this gas is passed through water holding any of the protein compounds, it gives a white, flocculent precipitate of—

Chloro-proteic Acid. Syn. Chlorite of protein, $C_{40}H_{31}N_5O_{12} + ClO_3$. When washed and dried at 212° , it is a straw-yellow powder, nearly insoluble in water and wholly insoluble in alcohol and ether. It dissolves in HCl acid, and nitric acid transforms it into xanthoproteic acid.

The action of boiling hydrochloric acid generates *Hydrochloro-proteic Acid*, $C_{80}H_{62}N_{10}O_{24} + H_2O_2 + HCl$. During the boiling, the solution, at first yellow, gradually changes to blue, provided the air is admitted.

Action of Nitric Acid. Nitric acid transforms protein or any of its modifications, with the

evolution of nitrogen, into nitrate of ammonia, oxalic and xanthoproteic acids.

Xanthoproteic Acid, $C_{34}H_{21}N_4O_{12} + 2HO$. An orange-colored, pulverulent, inodorous matter, insoluble in water, alcohol, and ether. It combines with both acids and bases. The alkaline salts are dark red, and soluble: the precipitates which they give with metallic salts are yellow.

Action of Water. Contact for several hours with boiling water and air, converts protein into a soluble and insoluble portion, which are termed respectively binoxide and tritoxide of protein.

a. *Binoxide.* Syn. Protoxide. $C_{40}H_{31}N_5O_{14}$. Is the undissolved residue. Exists in the buffy coat of the blood. Von Laer has also obtained it from hair. Is pale yellow while moist, but on drying forms a dark, resinous mass, which gives a deep amber-yellow powder, insoluble in alcohol and cold water. Dilute acetic, hydrochloric, nitric, and sulphuric acids dissolve it readily; from these solutions it is precipitated by acetate of lead, tannin, ferro and ferridcyanide of potassium. It is also soluble in potassa and ammonia. Treated with chlorine gas it becomes $C_{40}H_{31}N_4O_{17}$.

b. *Tritoxide.* Syn. Oxyprotein. $C_{40}H_{31}N_5O_{15}$, HO. Exists in the soluble portion. Is found also in the buffy coat of blood, and may be obtained from the chlorite of protein by the action of ammonia. A yellow powder, soluble in water and acids, but insoluble in alcohol, ether, and the oils. With the metallic oxides it forms a class of double salts of the formula $(C_{40}H_{31}N_5O_{15} + RO) + (C_{40}H_{31}N_5O_{15} + HO)$. Nitric acid converts it into xanthoproteic acid. Dilute acetic acid, neutral salts of potassa and soda, chloride of barium, hydrochlorate of ammonia, and ferrocyanide of potassium do not precipitate it, but it is always thrown down in the same manner from its aqueous solution by diluted nitric, sulphuric, hydrochloric, phosphoric, and tannic acids, by solutions of chlorine, bi-chloride of mercury, neutral and basic acetate of lead, nitrate of silver, sulphate of zinc, and peroxide of iron.

The most recent researches of Mulder lead to different views of protein and its derivatives or allied bodies. He regards protein or its bihydrate as $C_{36}H_{25}N_4O_{10} + 2HO$; that the sulphur and phosphorus present in albuminoids are in the form of sulphamide and phosphamide, SNH_2 and PNH_2 ; and that these albuminoids are compounds of $C_{36}H_{25}N_4O_{10}$, with different proportions of sulphamide and phosphamide. When albumen is treated with potassa, NH_3 passes off, and the sulphur of its sulphamide becomes hyposulphurous acid, S_2O_2 , which unites with the protein; the phosphamide becomes PO, which combines with the potassa. The properties of the salts of albumen and protein are almost identical. The sulphate has the form. $C_{36}H_{25}N_4O_{10} + (0.4 SNH_2) + SO_3HO$. The muriate is 5 equivs. albumen + 2 HCl. The action of chlorine is most clear; when passed into a solution of albumen and the action is not continued too long, it consists of chlorite of albumen = $C_{36}H_{25}N_4O_{10} + (0.4 SNH_2) + ClO_3, HO$; if the action be prolonged, it forms chlorite of protein = $C_{36}H_{25}N_4O_{10} + (0.2 S_2O_2) + 2 ClO_3$.

Biroxyprotein should be termed protoxyprotein, and its form. $C_{36}H_{27}N_4O_{12}$. Vitellin is a compound of oxyprotein with sulphamide. Tritoxyprotein is obtained by boiling albumen, fibrin, &c., with water, and exhausting with alcohol the residue from evaporation; its form. is $C_{36}H_{25}N_4O_{10} + O_2$.

Millon (*Comptes Rendus*, 1849) proposes as a delicate test for the protein compounds the very acid liquor obtained by dissolving mercury in its weight of nitric acid with $4\frac{1}{2}$ equivs. of water. This liquid communicates to albuminous substances a very deep red color, and in this way will detect even less than a hundred thousandth part of albumen in water. Xanthoproteic acid, the chlorites and oxides of protein, derived from the chlorites, are exceptions, and consequently, he infers, that the buffy coat of the blood is not identical with the oxides of protein, obtained by acting with potassa upon chlorites of protein.

PROTOGINE is granite with talc, instead of mica.

PROUSTITE. See RUBY SILVER.

PRUSSIAN BLUE. *Min.* See VIVIANITE.

PRUSSIAN BLUE.

PRUSSIC ACID. } See CYANOGEN.

PRUSSIATES. }

PSEUDOALBITE. *Min.* Andesin. Very similar to albite in external characters. $H. = 6$. $G. = 2.7328$. Form. $3 RO, 2 SiO_2 + 3 (R_2O_3, 2 SiO_3)$. From Marmato, in the Andes.

PSEUDOMALACHITE. See PHOSPHOR-CHALCITE.

PSEUDOMORPHISM. *Geol.* Also Pseudomorphs. *Ger.* Afterkristalle. A pseudomorph is a mineral body in a crystallized form that belongs to some other mineral. Thus quartz, of the hexagonal system, is found in the form of fluor spar, of the regular system. This is the more commonly received definition at present, but it is evident that we must expand our view of the subject, when it can be shown that the same causes of a pseudomorph have produced metamorphoses of rocky masses without, and perhaps often with changes of form. To embrace the whole, I have employed the term Pseudomorphism.

The full essay of Dr. Blum, *Pseudomorphosen des Mineralreichs*, 1843, and *Appendix*, 1847, Haidinger's essays, *Pog. An.* xi. and lxii; especially Bischoff's *Chemische und Physikalische Geologie*, 1847, Bd. II. pp. 186—508, together with smaller detached essays, by various authors, have greatly enlarged this subject, and promise to make it the most important branch of geology, in explaining the changes undergone by minerals and mineral masses, on the surface of the earth.

When great effects are observed, our first inclination is to ascribe them to powerful and suddenly-acting causes, such as the elevation of hills and mountain chains; but a more deliberate view of facts leads to the conclusion that the same results may be obtained by slowly-acting, long-continued, but perhaps not less powerful causes. In like manner the first tendency of those who examined pseudomorphs, was to attribute them to the agency of heat, electric currents, and the like. But Bischoff has shown very clearly that heat is not the cause of pseudomorphous changes. Dana, in

an essay, *Sill. Jour.* xlviii. 81 (which it is to be wished he had lengthened), has resorted to two causes, according to which he divides pseudomorphs, those formed at the ordinary temperature, and those requiring an elevated temperature. Haidinger and Blum seem inclined to ascribe many of these changes to powerfully heated vapors rising from beneath, and impregnating mineral substances near the surface.

Doubtless some few changes of this kind have occurred, but the amount of thermal action with which we are actually acquainted, on the surface of the globe, is too limited in its sphere to account for the wide-spread changes we witness. Moreover, the greater number of pseudomorphs contain water, or are found in such positions as give no other evidence of such an action, or are of such a nature as to preclude it. But in answer to all views, other than those which ascribe the changes to ordinary operations with which we are familiar, it may be asked, why resort to causes with which we are less acquainted, if those with which we are sufficient to account for the phenomena?

Calcareous spar is found in the form of gaylussite, and we may readily conceive that it was formed by the simple removal, through water, of hydrated carbonate of soda; but we must at the same time allow that carbonate of lime has also entered, or the calc. spar would be very porous. So we may conceive anglesite (sulphate of lead) to take the place of galena by simple oxidation; but the much greater bulk which the galena would thus assume, requires us to assume that a portion of the galena has been carried away. Where we find calc. spar in the form of gypsum, kaolin in that of feldspar and leucite, steatite in that of quartz, feldspar, spinell, garnet, augite, &c., since the pseudomorph contains one or more of the constituents of the body it imitates, we might suppose that a portion of the original matter has been removed, and other matter introduced. But we cannot positively assert this, for it is very possible that the whole of the original body may have been removed, and entirely new matter may have replaced it.

The above examples include what Blum terms Umwandlungs-Pseudomorphosen, Ps. by alteration, which he divides into those where a part of the original substance is removed, those where something new is added, and those where both operations have taken place.

The second of Blum's two classes, Verdrängungs-Pseudomorphosen, Ps. by supplanting or removal, he divides into those by incrustation, and those by substitution: that is, where a body has become incrustated by another mineral, and is then removed, leaving its cast; and where there is a gradual removal of a mineral and simultaneous deposition of other matter. But it is often difficult to say, when a pseudomorph has any one of the constituents of the original body, whether it is a part of the original, or whether the whole substance of the pseudomorph has been substituted for the original; it might therefore be formed by alteration. It may also happen that a crystal may become incrustated and then gradually removed, while the same matter as the incrustation fills up the cavity.

PSEUDOMORPHISM.

The minute distinctions drawn by Blum are not to be considered as perfectly correct, if received, for the pseudomorphic changes have been studied with too little accuracy, and a closer chemical examination will probably lead to better arrangement,—a classification which shall point out the manner of the change. Thus we find brown hematite in the form of calc. spar, and we may conceive the former to have precipitated from solution by the latter as a basic salt, which has subsequently lost its acid; and we can further conceive this oxide of iron to have become pyrites, which also occurs in the form of calc. spar. A classification on chemical principles, where they occur, will be the best. There are cases among the changes by substitution, where the operation is merely mechanical, where matter is deposited in the cavity of a crystal, which has long since disappeared.

There are considerable difficulties attending the study of pseudomorphic changes. The change cannot be observed. The inferences drawn from the composition of the crystal or body replaced, and that of the replacing matter, are to be drawn with great caution, since we know but little of the nature of chemical interchanges, excepting by laboratory experiments, and there may be, and probably is, a wide difference between the rapid decompositions of the laboratory, and the slow changes of nature. We lack the important element of time, ages, to attempt results in the laboratory similar to those observed in nature. Nevertheless, much may be done by experiment, and this, combined with close and extended observation, is sure to lead to good results. The waters of the earth have not yet been examined (with few exceptions) with that minuteness which this subject requires. But still enough is known to satisfy us that almost all, if not all, pseudomorphic changes may be referred to gradual alteration by the simplest aqueous causes now in action. It can even now be shown with much plausibility, that most of our rocks which are termed plutonic, have not been heaved up in the state in which we observe them; that they must have undergone important internal changes from the influence of aqueous solutions, and that some not stratified but apparently fused, may be shown not to be plutonic at all, but sedimentary rocks, altered by aqueous action.

To give a rather more complete view of pseudomorphism, I give a catalogue of pseudomorphs, from Blum's work, taken from *Sill. Jour.*, xlviii., p. 67. But I refer to the very full view of aqueous pseudomorphic changes, in Bischoff's work, cited above:—

CLASS I.

Subdivision 1.

Pseudomorph.	Form imitated.
Calc. spar,	Gay-lussite.
Kyanite,	Andalusite.
Steatite,	Hornblende.
Native copper,	Red copper ore.
Vitreous silver,	Red silver ore.

Subdivision 2.

Gypsum,	Anhydrite.
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PSEUDOMORPHISM.

Pseudomorph.	Form. imitated.
Mica,	Pinite.
Antimony bloom,	Native antimony.
Anglesite,	Galena.
Specular iron,	Magnetic iron.
Brown iron ore,	Specular iron.
Malachite,	Red copper ore.
Variegated copper ore,	Vitreous copper.
Copper pyrites,	Vitreous copper.

Subdivision 3.

Heavy spar,	Witherite, baryto-calcite, and calc. spar.
Calc. spar,	Gypsum.
Dolomite,	Calc. spar.
Chalcedony,	Datholite.
Jasper,	Hornblende.
Opal,	Augite.
Quartz,	Garnet.
Cimolite,	Augite.
Lithomarge,	Topaz, feldspar.
Kaolin,	Feldspar, porcelain spar, leucite.
Mica,	Andalusite, wernerite, tourmaline.
Prehnite,	Analcime, leonhardite.
Talc,	Kyanite, feldspar, pyrope.
Steatite,	Dolomite, spinel, quartz, andalusite, topaz, feldspar, mica, wernerite, tourmaline, staurotide, garnet, idocrase, augite.
Serpentine,	Augite, hornblende, chrysolite.
Chlorite,	Garnet, hornblende.
Hornblende,	Augite.
Green earth,	Augite.
Pyrolusite,	Manganite.
Hausmannite,	Manganite.
Antimony bloom,	Gray antimony.
Antimony ochre,	Gray antimony.
Antimony blende,	Gray antimony.
Bismuth ochre,	Needle ore.
Minium,	Galena, white lead ore.
Pyromorphite,	Galena, white lead ore.
White lead ore,	Galena, anglesite, leadhillite.
Molybdate of lead,	Galena.
Red iron ore,	Pyrites, cube ore, spathic iron.
Brown iron ore,	Ankerite, pyrites, white iron pyrites, scorodite, cube ore, spathic iron.
Göthite,	Pyrites.
Pyrites,	Mispickel.
Green vitriol,	Pyrites.
Pseudotriplite,	Triphylite.
Wolfram,	Scheelite.
Cobalt bloom,	Smaltine.
Black copper,	Vitreous copper.
Malachite,	Azurite, copper pyrites.
Chrysocolla,	Copper mica and red copper ore.

CLASS II.

Common salt,	Dolomite.
Anhydrite,	Common salt.
Gypsum,	Common salt.
Polyhalite,	Common salt.
Carbonate of strontian,	Gypsum.

Pseudomorph.

Form imitated.

Quartz,

Heavy spar, fluor spar, gypsum, calc. spar, baryto-calcite, dolomite, scheelite, galena, white lead ore, specular iron, pyrites, spathic iron:—as *Prase*, calc. spar:—as *Chalcodony*, heavy spar, fluor spar, calc. spar, dolomite, pyromorphite:—as *Carnelian*, calc. spar:—as *Hornstone*, fluor spar, calc. spar, mica, spathic iron:—as *Semiopal*, calc. spar.

Lithomarge,

Fluor spar.

Feldspar,

Calc. spar.

Meerschbaum.

Calc. spar.

Pyrolusite,

Calc. spar.

Hausmannite,

Calc. spar.

Manganite,

Calc. spar.

Psilomelane,

Heavy spar, fluor spar, cube ore.

Calamine,

Fluor spar, calc. spar.

Electric calamine,

Fluor spar, calc. spar, dolomite, galena, pyromorphite.

Tin ore,

Feldspar.

White lead ore,

Heavy spar, fluor spar.

Peroxyd of iron,

Fluor spar, calc. spar.

Brown iron ore,

Heavy spar, fluor spar, calc. spar, dolomite, quartz, comptonite, blende, galena, pyromorphite, white lead ore, red copper ore.

Pyrites,

Heavy spar, calc. spar, quartz, brittle silver ore, red silver ore.

White iron pyrites, Brittle silver ore.

Spathic iron,

Calc. spar, dolomite.

Malachite,

Calc. spar, white lead ore.

Chrysocolla,

White lead ore.

Green earth,

Haydenite.

Chlorophyllite and

fahlunite,

Iolite.

Rensselaerite,

Augite.

PSEUDOQUININE. A new alkaloid, found by Mengardue in a bark of unknown origin. (*Liebig's Annalen*, lxxi., p. 128.)

PSEUDOTRIPLITE. *Min.* Accompanies the triplite of Bodenmais, and its formula is $3\text{Fe}_2\text{O}_3 (\text{Mn}_2\text{O}_3), 2\text{PO}_5 + 2\text{HO}$.

PSILOMELAN. *Min.* Black iron ore. Massive and botryoidal. $\text{H.} = 5 - 6$. $\text{G.} = 4 - 4.328$. Black, passing into dark steel-gray; submetallic; opaque; streak brownish black, shining. Yields water in a tube, and behaves like oxide of manganese to the fluxes. Soluble in muriatic acid with strong evolution of chlorine. Rammelsberg gives as its form. RO , $2\text{MnO}_2 + \text{HO}$, in which RO is BaO , CaO , KO , CoO , CuO , and probably MnO . It is an abundant ore of manganese, usually accompanying pyrolusite, and affords a tolerable amount of chlorine; but the RO bases are wasteful of acid.

PUCHA PAT. A plant of the genus *Labiata*, growing wild in Malaga, and used in Hindostan as an ingredient in tobacco for smoking, and for scenting the hair of the women. Its perfume is due to volatile oil. The Arabs employ

the dried leaves for stuffing mattresses, under the belief that it prevents contagion. (*Chem. Gaz.* i. 408.)

PUDDING-STONE. *Geol.* A name sometimes given to a conglomerate of rolled pebbles.

PUMICE. *Geol.* A porous, spongy, volcanic scoria, lighter than water. It is probably a mixture of several minerals, and of different mineral compositions, in different localities, and possibly at different eruptions. There can be little doubt that it is formed by the contact of water with fused mineral matter, and can be imitated by watering the slag of an iron-furnace.

PUNICIN. Obtained in crystals by Righini, from the root-bark of the *Punica granatum*, by precipitating the alcoholic tincture with water.

PURPLE COPPER. See **VARIEGATED COPPER.**

PURPLE OF CASSIUS. See **GOLD**, p. 623.

PURPURIC ACID. See **URINE.**

PURPURIN. See **MADDER.**

PURREE. A yellow substance, from India, which yields the pigment known as "*Indian yellow*." When treated with acetic acid it gives a liquor that, after filtration and precipitation by acetate of lead, gives, on the decomposition of the lead salt by sulphuretted hydrogen, a yellow, crystalline body, which Stenhouse has named—

Porrière acid, $\text{C}_{20}\text{H}_9\text{O}_{11}$. Crystallizes in long, silky, yellow needles, soluble in boiling alcohol and water, and in ether. It colors the alkalies deep yellow, and forms yellow precipitates with most of the metallic solutions. When heated above 212° , it gives a crystalline sublimate, *Purrenon* ($\text{C}_{13}\text{H}_4\text{O}_4$), slightly soluble in water, soluble in alcohol and ether, but without acid properties.

PUS. The matter secreted by ulcerated textures, and particularly by the cellular membrane. In the normal state it is a thick, viscid liquid, yellowish or greenish, and consists of a fluid portion, or liquor puris, filled with floating, oval, insoluble corpuscles, and precipitated upon the addition of water. Heat and acids both coagulate it. It may be distinguished from mucus by its forming a thick, ropy solution with caustic potassa. Gütterbock's analysis gives, as its composition,—

Water	861.0
Solid constituents	139.0

Fat soluble only in hot alcohol	16.0
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Fat and extractive matter soluble in cold alcohol	43.0
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Albumen, pyin, and pus-corpuscles	74.0
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Pyin. According to Eicholz, it is identical with mucin; and Mulder considers it the same as tritoxide of protein; but Eicholz's pyin differs from the protein compounds in being precipitated from an alkaline solution by an aqueous solution of iodine, and by distilled water. Is soluble in water and weak alcohol, and does not coagulate when boiled. By drying it becomes a gray powder, and then its solubility is impaired. Acetic acid, tannin, and alum give precipitates insoluble in an excess of the reagent.

PUSCHKINITE. See **EPIDOTE.**

PUTREFACTION. See **FERMENTATION.**

PUZZOLANA. *Geol.* Volcanic ashes from

Vesuvius, $\frac{1}{4}$ decomposable by muriatic acid, and $\frac{3}{4}$ not decomposed; the latter is probably a potassa-soda-feldspar.

PYCNITE. See TOPAZ.

PYIN. See PUS.

PYRALOLITE. *Min.* Cryst. Triclinic, with distinct prismatic cleavage; generally granular. $H. = 3.5-4$. $G. = 2.55-2.59$. White, greenish; dull; subtranslucent, opaque. It blackens on coal, then becomes white; intumesces and fuses on the edges to a white enamel; gives with soda a clear glass, usually colored green by iron. Its formula is doubtful, but Kobell suggests MgO, SiO_3 , with MgO, HO . It occurs in Pargas, Finland.

PYRANTIMONITE. See RED ANTIMONY.

PYRARGILLITE. *Min.* Massive, occasionally as a 4-sided prism, probably a pseudomorph. Black and shining, or bluish and dull. Yields water, gives by heat an argillaceous odor, is infusible, swells up with soda to a gray scoria. Form. $FeO, SiO_3 + Al_2O_3, SiO_3 + 4 HO$. Helsingfors, Finland.

PYRENAITE. See GARNET.

PYRETHRIN. A soft, acrid resin, the active principle of the *Anthemis Pyrethrum*. Is insoluble in water, but soluble in alcohol and ether. According to Koene, it consists of three different substances:—1. a very acrid, resinous, brown matter, soluble in alcohol and insoluble in water and potassa; 2. a fixed oil, very soluble in alcohol; and 3. a yellowish oil, soluble in potassa, alcohol, and ether.

PYRGOM. See AUGITE.

PYRITES. *Min.* Yellow or white sulphurets, sometimes with arseniurets of iron, copper, cobalt, nickel. See Iron P., Copper P., Cobalt P., Copper nickel, Mispickel, &c.

PYRO. When, in certain instances, a body, by the action of heat, is modified into a new product, the title of the latter has a prefix of pyro, to distinguish it from the original substance. Thus, for example, gallic—pyrogallic acids.

PYROACETIC SPIRIT. See ACETONE.

PYROCHLORE. *Min.* Microlite (?). Cryst. Regular, 8-hedron, Pl. VIII., fig. 1, also fig. 3, and a combination of figs. 1 and 10. $H. = 5-5.25$. $G. = 3.8-4.32$ (5.5 microlite). Honey-yellow, brown; vitreous or resinous; subtransparent, opaque; conchoidal fracture. On coal it becomes yellow, and fuses with great difficulty to blackish brown scoria; in borax in the outer flame to reddish yellow, in the inner dark red; in mic. salt, in the outer yellow while hot, green on cooling, in the inner flame dark red to violet; some show uranium, some manganese with soda. Decomposed by oil of vitriol, readily by warming. If the columbic acid = Ta_2O_3 , Wöhler's formula is $NaF + 2 CaO, Ta_2O_3$; but if it be TaO_2 (Rose), it is $NaF + 2 (4 CaO, 3 TaO_2)$. The CaO includes ThO and CeO . There are also present $TiO_2, U_2O_3, FeO, MnO, YO (KO, LiO ?)$. Herrmann's view that the thorina is zirconia and lithia, is disproved by Wöhler and Berzelius. It occurs at Friedericksvärn, Laurvig, Erevig in Norway; Miask, Siberia. Microlite from Chesterfield, Massachusetts, is placed by Shepard and Hayes with pyrochlore, but the formulæ are different.

PYROCITRIC ACID. See CITRIC and ACOTIC ACIDS.

PYROGALLIC ACID. See GALLIC ACID.

PYROLIGNEOUS ACID. See ACETIC ACID, p. 22.

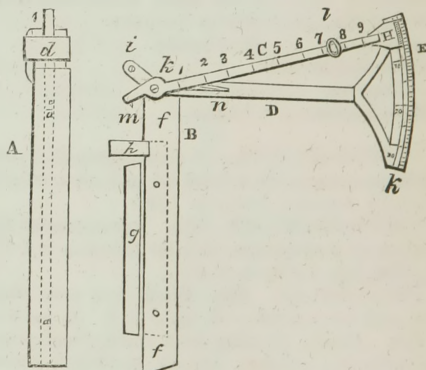
PYROLUSITE. *Min.* Gray manganese, Glassmakers' soap. Cryst. Right rhombic, with a vertical cleavage; also columnar and granular. $H. = 2-2.5$. $G. = 4.8-4.97$. Black, sometimes bluish; metallic lustre, if crystalline; opaque, rather sectile, with black streak. Distinguished from psilozelan by hardness and streak. Yields little or no water, and behaves like oxide of manganese to the fluxes. Soluble in muriatic acid with strong evolution of chlorine. Form. MnO_2 . An abundant, and the most valuable ore of manganese, and is largely used in making chloride of lime, and in decolorizing glass, whence one of its names.

PYROMARIC ACID. See COLOPHONY.

PYROMETER. An instrument for the measurement of high temperatures. It will not indicate the amount of contained heat, but like the THERMOMETER, determines only the comparative temperature of two or more bodies.

Pyrometers are constructed of solid substances, though gaseous bodies, on account of their sensitiveness to heat and cold, or greater uniformity of expansion, would be preferable. Wedgwood's pyrometer is the oldest instrument, but Daniell's instrument is the most approved, and by skilful management may be made to give accurate indications. Its principal application is in furnace operations. In assaying, where the required temperature varies with the metal under process, it is particularly available in determining the heat of the furnace; for much of the accuracy of the assay depends upon the temperature at which it is made. Fig. 89 represents the apparatus.

Fig. 89.



It consists of two parts, which may be distinguished as the register 1, and the scale 2. The register, A, is a solid bar of black lead earthenware, highly baked. In this a hole, aa, is drilled, into which a bar of any metal, six inches long, may be dropped, and which will then rest upon its solid end. A cylindrical piece of porcelain, c, called the index, is then placed upon the top of the bar, and confined in its place by a ring or strap of platinum, d, passing round the top of the register, which is partly cut away at the top, and tightened by a wedge of porcelain, e. When such an arrangement is exposed to a high temperature,

PYROMETER.

it is obvious that the expansion of the metallic bar will force the index forward to the amount of the excess of its expansion over that of the black lead, and that when again cooled it will be left at the point of greatest elongation. What is now required, is the measurement of the distance which the index has been thrust forward from its first position, and this, though in any case but small, may be effected with great precision by means of the scale.

This is independent of the register, and consists of two rules of brass, *ff* and *g*, accurately joined together at a right angle by their edges, and fitting square upon two sides of the black lead bar. At one end of this double rule a small plate of brass, *h*, projects at a right angle, which may be brought down upon the shoulder of the register formed by the notch cut away for the reception of the index. A movable arm, *d*, is attached to this frame, turning at its fixed extremity on a centre, *i*, and at its other carrying the arc of a circle, whose radius is exactly five inches, accurately divided into degrees and thirds of a degree. Upon this arm, at the centre of the circle, *k*, another lighter arm, *c*, is made to turn, one end of which carries a nonius, *n*, with it, which moves upon the face of the arc, and subdivides the former graduation into minutes of a degree; the other end crosses the centre, and terminates in an obtuse steel point, *m*, turned inwards at a right angle.

When an observation is to be made, a bar of platinum or malleable iron is placed in the cavity of the register; the index is to be pressed down upon it, and firmly fixed in its place by the platinum strap and porcelain wedge. The scale is then to be applied by carefully adjusting the brass rule to the sides of the register, and fixing it by pressing the cross piece upon the shoulder, and placing the movable arm so that the steel part of the radius may drop into a small cavity made for its reception, and coinciding with the axis of the metallic bar. The minute of the degree must then be noted, which the nonius indicates upon the arc. A similar observation must be made after the register has been exposed to the increased temperature which it is designed to measure, and again cooled, and it will be found that the nonius has been moved forward a certain number of degrees or minutes. The scale of this pyrometer is readily connected with that of the thermometer, by immersing the register in boiling mercury, whose temperature is as constant as that of boiling water, and has been accurately determined by the thermometer. The amount of expansion for a known number of degrees is thus determined, and the value of all other expansions may be considered as proportionate.

The following is a list of the melting points of some of the metals, and it is obvious that in an assay of each particular metal, the temperature employed must exceed by a considerable number of degrees its melting point. The table is, therefore, very useful.

	Fahrenheit.
Tin melts at.....	422°
Bismuth.....	497
Lead.....	612
Zinc.....	773

PYROSMALITE.

	Fahrenheit.
Cadmium.....	442°
Silver.....	1860
Copper.....	1996
Gold.....	2016
Cast iron.....	2786
Cobalt and nickel rather less fusible than iron. (<i>Morfil's Manipulations</i> , pp. 136—138.)	

PYROMORPHITE. *Min.* Phosphate of lead; Grün- and Braunbleierz. Cryst. Hexagonal; also in imitative forms, fibrous and granular. *H.* = 3·5—4. *G.* = 6·587—7·048. Green, yellow and brown; resinous; subtransparent, subtranslucent; brittle with white or yellowish streak. For behavior see **MIMETESITE**; but it may not yield an arsenical odor. Formula, see **ARSENIOPHOSPHATES**. It occurs not rarely in lead mines; fine specimens of green and gray from Washington mine, Davidson Co., N. Carolina, and a few from Perkiomen, near Philadelphia.

PYROPE. See **GARNET**.

PYROPHORUS. From πυρ, fire, and φεω, to bear, because of its property of igniting spontaneously when exposed to air.

Homburg's pyrophorus is made by mixing thoroughly one part of sugar with three of alum, evaporating to dryness, and then heating to redness in a retort, until flame ceases to be emitted. Wackenroder prepares a very dangerous pyrophorus by igniting tartar emetic in a closed crucible.

PYROPHOSPHORIC ACID. See **PHOSPHORUS**.

PYROPHYLLITE. *Min.* Foliated; *H.* = 1; white, greenish, yellowish; pearly; translucent. Yields water, swells in the pincette into distorted forms, of a white color, and gives a fine blue with cobalt solution. Form. 3 MgO, 2 SiO₃ + 9 (Al₂O₃, 2 SiO₃) + 9 HO (empirical MS₂ + 9 AS₂ + 3 Aq). It occurs near Beresof, Ural. The vermiculite of Milbury, Massachusetts, is probably the same.

PYROPHYSALITE. See **TOPAZ**.

PYRORHITHITE. *Min.* Crystalline. *H.* less than 3. *G.* = 2·15—2·25. Brownish black; resinous; opaque; fracture conchoidal, splintery, earthy. Resembles orthite. Yields water and empyreumatic matter, and becomes black; heated on coal it continues ignited of itself, burning white and porous; behaves otherwise like orthite. Berzelius regards it as orthite mixed with $\frac{1}{2}$ silicates of RO bases, and coal and water. The carbon and water amount to 31·41 pr. ct. It occurs near Fahlun, Sweden.

PYROSIDERITE. See **BROWN HEMATITE**.

PYROSKLERITE. *Min.* Rhombic prism. *H.* = 3. *G.* = 2·74. Green; pearly; translucent; fracture uneven, splintery. Yields water; fuses with difficulty to a grayish glass; gives a chrome-green bead with borax; decomposed by muriatic acid. Form. 2 (3 MgO, SiO₃) + Al₂O₃, SiO₃ + 4 HO. Hartwall gives the same formula for kammererite, which contains 6 HO. From Elba and Aker, in Südermanland.

PYROSMALITE. *Min.* Cryst. Hexagonal, with perfect vertical cleavage; also massive. *H.* = 4—4·5. *G.* = 3·81. Liver-brown, passing into gray and green; pearly; brittle with

uneven fracture. In a closed tube it yields water, and then yellow drops of chloride of iron; fuses on coal, and with the fluxes gives the reactions of iron, manganese, and silex; with mic. salt, containing copper, it shows the presence of chlorine. Decomposed by nitric acid. Formula, $(\text{Fe}_2\text{Cl}_3, \text{Fe}_2\text{O}_3 + 6\text{HO}) + 4(3\text{FeO}, 2\text{SiO}_3 + 3\text{MnO}, 2\text{SiO}_3)$, or $\text{Fe}_2(\text{OCl})_3, 3\text{HO} + 4(3\text{RO}, 2\text{SiO}_3)$. From an iron mine of Nordmark, Wärmeland, Sweden.

PYROXANTHIN. See TARTARIC ACID.

PYROXANTHIN. *Chem.* Syn. Eblanin. Obtained by Scanlan from crude pyroxalic spirit. Form. $\text{C}_{21}\text{H}_9\text{O}_4$ (Gregory). According to Schweizer (*Journ. für Prakt. Chem.* 1848), pyroxanthin does not exist as such in the crude pyrolignic liquor, but is generated by the action of alkalis and alkaline earths upon pyroxanthogen, one of the constituents of the empyreumatic oil, a neutral resin and a volatile acid being simultaneously formed.

It crystallizes in yellow needles, soluble in hot alcohol, ether, and acetic acid, but insoluble in water, caustic potassa, and ammonia. Its solution in sulphuric acid is bluish red, and that in HCl acid purple, gradually passing into brown. Heated to 273° in the open air, it sublimes unaltered; but if confined, it decomposes.

PYROXEN. See AUGITE.

PYROXYLIC SPIRIT. Hydrate of oxide of METHYL.

PYROXYLIN. See GUN COTTON.

PYRRHITE. *Min.* Cryst. Regular, 8-hedron. $\text{H} = 6$. Orange-yellow; subtranslucent; vitreous. Infusible; splinters of it blacken on the end, and color the flame yellow. Insoluble in muriatic acid. From Mursinsk.

PYRROLE. *Chem.* An alkaloid found by Runge and Anderson in coal tar. It is yet to be examined.

Q.

QUARTATION. See GOLD.

QUARTZ. *Min.* Syn. Silex, Rock crystal, Flint, Agate, Jasper, Heliotrope, Chalcedony, Cat's eye, Amethyst, Prase, Chrysoprase, Basanite, Hornstone. *Ger.* Bergkrystal, Kiesel, Feuerstein, &c.

Cryst. Hexagonal, usually in prisms, terminated by 6-sided pyramids; the latter often elongated; also granular, compact (as in chalcedonies and jaspers), rarely fibrous. $\text{H} = 7$. $\text{G} = 2.64 - 2.67$. Color white, if pure, but presenting nearly every color, and of different shades in its numerous varieties; lustre vitreous, rarely resinous; transparent, opaque; tough, rather brittle with conchoidal to subconchoidal fracture.

In its purest state it is infusible; fuses with borax to difficultly fusible glass; is scarcely dissolved by mic. salt; and fuses readily with soda to a clear bead. Iron is frequent in the colored varieties. It is insoluble in every acid except fluohydric; the crystallized variety is scarcely soluble in boiling potassa lye, the amorphous variety much more so. It is essentially silica or silicic acid, SiO_2 .

Varieties, Localities. There are two sub-species, the crystallized and the amorphous, the

former mostly transparent, and with a pure vitreous lustre, the latter translucent to opaque, with a subvitreous, resinous, or waxy lustre, and often dull.

a. *Crystalline.* Rock crystal is applied to that nearly or quite colorless; Amethyst to the violet colored; Rose quartz to the rose colored; False Topaz to the yellow; Smoky Q. to that having a carbonaceous color, often so deep as to be nearly black; Milky Q. to a white variety, which sometimes has a greasy lustre; Prase to the green; Aventurine Q. to a reddish brown variety, filled with spangles of mica and fissures; Ferruginous Q. to a brownish red or ochrey variety, containing oxide of iron.

b. *Amorphous.* Chalcedony includes those of a milk-white or bluish white tint, and when traversed by asbestos and cut in a peculiar way, it is Cat's eye; Carnelian, bright to brownish red, and when very deep in color is Sard; Chrysoprase, green, colored by nickel; Agate consists usually of concentric or parallel layers of different colors, and presents different appearances, according to the mode of cutting it; dendritic appearances in it constitute moss-agate; Onyx consists of flat layers of white and black, or brown; and if the latter be deep brown, it is Sardonyx.

The above varieties are usually more or less translucent, but the following are more or less opaque. Jasper shows a mixture of many colors, of which red and green predominate; when in bands, it is Striped Jasper. Green jasper, with yellow and whitish dots, is Plasma; with blood-red spots, is Heliotrope. Flint is gray, smoky, and nearly black, and is characterized by its perfect and large conchoidal fracture. Hornstone is more brittle than flint, and has a more splintery fracture; when tough and of a black color, it is Basanite, Lydian-stone, or Touchstone.

Crystalline quartz, usually colorless and white, occurs in rock formations of every geological age. The chalcedonic varieties generally occurs lining cavities in various rocks. Flint occurs in nodules in chalk, and hornstone seems to be its equivalent in other limestones. The purer varieties, including flint, are largely employed in the manufacture of glass and fine pottery. Basanite is used to try the streak of gold and silver alloys. The rest are more or less employed as gems.

QUASSIA. *Pharm.* The wood of the *Q. excelsa*. It contains volatile oil, quassin, gummy extractive, pectin, lignin, and salts.

Quassin. Syn. Quassite. The bitter principle, $\text{C}_{10}\text{H}_6\text{O}_3$. (Wiggers.) Crystallizes in small white prisms, of bitter taste. Very soluble in alcohol, and but slightly in water and ether. Though neutral, it is soluble in nitric and sulphuric acids.

QUERCIN. A white or yellowish crystalline solid, extracted from the *Quercus robur*, by Gerber, (*Chem. Gaz.* i. 509). It is a neutral, bitter principle, soluble in water and alcohol, but insoluble in ether, strong alcohol, and oil of turpentine. Its solution is precipitated by salts of lead, silver, tin, and protoxide of mercury.

QUERCITRON. *Chem. Tech.* The bark of the *Quercus tinctoria*, or black oak. Much used as a dye-stuff, because of its yellow coloring principle, which is called—

Quercitrin. Syn. Quercitric acid, $C_{16}H_8O_9 + HO$. (*Bolley*.) Crystallizes in light grayish scales, which yellow on exposure to air. Is volatile and very soluble in water, alcohol, and ether, and leaves a bitter after-taste. Both acids and alkalies yellow it. The red and brown coloring matters accompanying it in the bark are, according to Preisser, modifications of quercitrin.

The formula of its lead salt is $C_{16}H_8O_9 + PbO$ (*Bolley*), $2(C_{32}H_{15}O_{14}) + PbO$ (*Preisser*). By boiling it deposits small acicular crystals of—

Quercitrein. Less soluble in water than the above, and forms a beautiful golden-yellow lead salt, of the composition $C_{32}H_{15}O_{13} + PbO$ (*Preisser*). *Chem. Gaz.* ii. 412.

QUICKSILVER. See MERCURY.

QUINCITE. See MEERSCHAUM.

QUINIC ACID. Syn. Kinic acid, Cinchonic acid, $C_7H_6O_6$ (crystallized). Exists in the different quinquina barks, in natural combination with quinin and cinchonin. Berzelius announced its existence in the albumin of the *Pinus sylvestris*, but Wöhler and Stenhouse have recently proved to the contrary. Forms colorless, transparent crystals, soluble in alcohol and water. Heated to 536° in a retort with manganese and sulphuric acid, it is decomposed into new products, among which is—

Quinone (*Quinoyle*). Crystallizes in beautiful yellow prisms, fusible and volatilizable without alteration. Is soluble in water. Wöhler and Stadler's recent analyses have confirmed Wokresensky's original formula, $C_{10}H_6O_2$.

QUINIDIN. Exists with quinin in one of the new barks resembling huamalies. Crystallizes in very minute, rhombic tablets. Soluble in alcohol, and sparingly in water. Its sulphate strongly resembles that of quinin.

QUININ. *Chem. Pharm.* Syn. Chinin, Quinia. An alkaloid, existing in the bark of several species of *quinquina*. It is generally found with CINCHONA, combined with QUINIC ACID and cinchonic red. The three principal kinds of genuine bark are—

1. The royal yellow or Calasaya, from the *Cinchonia cordifolia*.

2. The crown or Loxa bark, from the *C. condaninea*.

3. The red bark, from the *C. oblongifolia*.

Quinin predominates in the Calasaya, cinchona in the gray, while in the red the two are present in nearly equal proportions.

Quinin has also been found by Coxé in the *Pinckneya pubens*, and by Pelletier and Carenton in the *Portlandia hexandra*.

Calasaya bark yields 24 to 32 grammes of sulphate of quinin to the kilogramme.

Loxa (gray) yields 12 to 16 grms. sulphate of cinchona.

Lima (gray) yields 12 grms. sulphate of cinchona.

Bright red yields 16 grms. sulphate of quinin, and 8 sulphate of cinchonin.

Pale red yields 12 grms. sulphate of quinin, and 8 sulphate of cinchonin.

Spongy Carthagena yields 3 to 4 grms. sulphate of cinchonin.

Prep. a. Take of Calasaya bark, coarsely ground, a sufficient quantity for filling three-

fourths the capacity of the DISPLACEMENT apparatus, fig. 42, p. 522, and continue to exhaust it of soluble matter with acidulated water (10 lbs. oil of vitriol to 30 galls. water), until the liquid passing through is colorless, tasteless, and gives no reaction with ammonia. To the warmed liquors thus obtained, add milk of lime, little beyond neutralization. By this reaction the quinin is precipitated with the lime, and after subsidence may be freed of the supernatant liquor by decantation. The precipitate is then to be drained upon a filter, pressed, broken into small pieces, dried, and powdered. This powder is now to be placed in a displacing cylinder, and treated with alcohol of 34° B., until it ceases to give soluble matter to the liquor. The charged liquor is then to be distilled so as to recover three-fourths of the alcohol, and the residue transferred to a basin, and exactly neutralized with dilute sulphuric acid. In several hours the whole will have crystallized, and, in order to separate the black mother waters, must be enclosed in a linen cloth and tightly pressed. The impure cake of quinin, upon resolution and repeated crystallization from water, by the aid of bone-black, acquires a sunny whiteness. These crystals are to be very carefully removed, placed upon frames, and dried in a warm, not a hot room, else effervescence will ensue, and the beauty of the crystals be impaired. From a solution of these crystals quinin may be precipitated by ammonia, and crystallized from solution in alcohol of 90 pr. ct. In order to separate the total content of alkaloids from the mother water (which retains any cinchonin that may have been in the bark), they must not be evaporated, but precipitated by carb. soda. The precipitate thus produced, after being drained upon a cloth and pressed, is to be mixed with a quantity of water, not too great to make a dilute solution, and neutralized while boiling with sulphuric acid. By repose the sulphate crystallizes, and may be purified as above directed. In the same way, another portion of quinin may be separated from the residual liquors, and when they cease to yield, by this mode, any more crystalline salt, they are to be set aside to be made into QUINOIDIN. The last products are more or less mixed with cinchonin, though the most of the alkaloid remains in the extract. The last precipitations therefore, instead of being neutralized with SO_3 , may better be treated with alcohol of 64° , which dissolves out the quinin and leaves the cinchonin. The alcoholic tincture can be neutralized as before, and set aside to crystallize.

To exhaust the extract entirely, Guibourt adds an equal weight of solution of common salt of 15° B., boils the mixture for a quarter of an hour, decants, and subjects the brown residue again and again to the same treatment.

The liquors are then to be united, filtered, and when cold precipitated by ammonia. The brown precipitate is to be redissolved in water and dried, portionwise, with ammoniacal solution of salt, to partial saturation only. The soft brown deposit first formed is to be separated, and the precipitation afterwards completed with ammonia. From this precipitate

alcohol dissolves the sulphates of quinin and cinchonin.

Some chemists, in the preceding process, substitute HCl for sulphuric acid, which gives the advantage of less precipitate to dry and powder, as the chloride of calcium is entirely, while the sulphate is only partially soluble. Boiling in kettles by the direct application of fire, as is practised in many of the laboratories, is less economical and more laborious than exhausting by displacement. Displacing apparatus are made with outer jackets, for the application of heat by means of steam; but a previous warming of the acidulated water, in this instance, suffices.

b. Lebourdais (*Ann. de Chim. et Phys.* 1848) prepares quinin by passing the sulphated decoction, made as above directed, through bone-black. The charcoal, when washed, dried, and treated with alcohol of 0.848, yields a liquid which, on evaporation, becomes milky, and drops crystals of quinin.

Prop. $C_{20}H_{12}NO_2$. Eq. 412, or $C_{20}H_{12}NO_4$ (*Duflos*). A hard, white mass, of a resinous fracture. May be obtained in prisms by crystallization from its solution in absolute alcohol. Contains 14.1 pr. ct. of water, which it loses by fusion. Is soluble in alcohol and ether, and but very slightly in water, and forms salts with the acids. Tannin and gallic acid precipitate an aqueous solution of quinin, but the most delicate test is that of Andre. To the muriated or sulphuretted solution add chlorine water, and then aqua ammonia; a beautiful green tint is assumed, which is changed to deep red by an acid. Quinin is the only alkaloid known to give this characteristic reaction. One part of crystallized quinin is equivalent to—

1.15	parts of sulphate,
1.01	“ “ acetate,
1.01	“ “ citrate,
1.05	“ “ tartrate,
0.95	“ “ chlorhydrate,
1.01	“ “ ferrocyanate.

Salts. 1. *Sulphate.* Light, feathery crystals, of snowy whiteness. The salt of commerce, the most important, is basic, and has the formula $2\overset{+}{Q} + SO_3 + HO$. It is soluble in alcohol and hot water, but not so readily in the bi-salt.

2. *Muriate.* Pearly needles, more soluble than the sulphate.

3. *Acetate.* Crystallizes in silky needles.

4. *Citrate.* Nearly insoluble.

5. *Tartrate.* Nearly insoluble.

6. *Ferrocyanide.* $C_{20}H_{12}NO_2 + CfyH_2 + 3HO$ (*Duflos*). Crystallizes in groups of yellow, efflorescent needles, soluble in alcohol, but nearly insoluble in water.

7. *Ferridcyanide.* $2(C_{20}H_{12}NO_2) + Cfy_2H_3 + 3HO$. Crystallizes in laminae, readily soluble in water.

8. *Valerianate.* Crystallizes in colorless, rhombic, tasteless, or opaque octahedral prisms, soluble in water, alcohol, ether, and oil. It contains 2 equivs. of water, one of which it loses at 194°, becoming a resinous mass, insoluble in water. Prolonged ebullition has the same action. (*Chem. Gaz.* iii. 326.)

9. *Kinate.* Exists naturally in the bark, and

forms crystals soluble in water and dilute alcohol, but insoluble in alcohol of 36°.

Action of Potassa upon Quinin. When quinin is heated in a retort with a very dense solution of caustic potassa, hydrogen is evolved, an oily liquid of basic properties passes over. Gerhardt (*Journ. für Prakt. Chem.* xxviii. 61) called it *Chinolein* (Syn. Quinolein); and recent researches have shown its identity with *Leucole* (*Leucolin*), found in coal tar.

Adulterations of Quinin and its Sulphate. Sulphate of lime, magnesia, boracic and stearic acids, cinchonin, salicin, mannite, sugar, and starch are the usual sophistications. Cinchonin is frequently more or less mixed with quinin made from inferior barks; but when the proportion exceeds 4 pr. ct., its presence may be considered a fraud. To detect it, the salt is to be dosed with ammonia, and the precipitate treated with ether, which dissolves the quinin and leaves the cinchonin. It may be detected by the direction in which it rotates upon the plane of polarization, which is to the right, while quinin rotates to the left.

Salicin is detected by the red color which it gives to sulphuric acid, while, during this reaction, if any stearic acid, starch, or sulphate of lime is present, it will remain undissolved, and any sugar will be charred. (*Chem. Gaz.* iii. 107, 395.) Alcohol leaves gypsum, chalk, and magnesia untouched, and when tinctured with boracic acid, imparts a green color to flame. Starch is also detected by iodine, and sugar and mannite may be extracted by cold water.

Another very prevalent fraud is to mix the acid with the neutral salt, by which the decrease of the amount of quinin proper is in a ratio with the excess of water and sulphuric acid. The fraud may be detected by the greater solubility of the former, which requires but 11 pts. of water, whereas the neutral salt must have 740 pts. Moreover, it loses 10.75 pr. ct. of water by efflorescence (at 212°), and the acid salt 24 pr. ct.

QUINOIDIN. Syn. Amorphous Quinin, Chinoidin. This name is given to the extractive matter or uncrystallizable mother water obtained in the manufacture of sulphates of quinin and cinchonin. Setturner, among others, described it as a new alkaloid with peculiar properties, but Liebig afterwards announced it to be quinin in an amorphous or uncrystallizable state. The more correct view, probably, is, that it consists of quinin and cinchonin, accompanied by resinous matter, which prevents their crystallization. Winckler detects the presence of crystalline alkaloids in quinoidin, by adding hyposulphite of soda to the muriate, which precipitates hyposulphite of quinin in dazzling white crystals, and the same salt of cinchonin in four-sided needles, whereas, under the same circumstances, the amorphous alkaloids do not yield these precipitates. Roder gives the following method for the separation of the first two from the latter, in a crystalline form:—

1 pt. of commercial quinoidin is dissolved in 4 pts. alcohol of 0.865, and a solution of $\frac{1}{2}$ a part of protochloride of tin in 2 pts. of water added to it. This precipitates a dark, resinous mass, while the supernatant liquid is but

QUINOLIN.

faintly colored; it is separated from the precipitate, and quickly precipitated with ammonia. The precipitate is then well washed and dried, and exhausted with alcohol as long as this removes any thing; the united extracts are again mixed with half the former amount of protochloride of tin, again quickly precipitated with ammonia, and the well-washed and dried precipitate exhausted with alcohol, when an almost colorless solution of pure quinin is obtained, which, carefully saturated with dilute sulphuric acid, affords on evaporation crystals of sulphate of quinin.

In the liquid filtered from the precipitate of protoxide of tin and quinin, as well as in the wash-water, cinchonin is contained, if ordinary quinoidin has been employed which has not been previously purified by precipitation with an alkali. These liquids, containing cinchonin, are precipitated with tincture of galls, to obtain the cinchonin in the usual manner.

The precipitated resinous substance still retains some quinin, to obtain which it is dissolved in alcohol, again mixed with a strong solution of protochloride of tin, and then further treated in the above-mentioned manner. The resinous substance so obtained is of an alkaline nature, of a bitter taste, and possesses the peculiar odor of quinoidin; it would probably yield more quinin on further treatment.

The author obtained, by this process, from two different samples of quinoidin, in one case 43 pr. ct. quinin, 9 pr. ct. cinchonin, and 28 pr. ct. resin; and in the second 40 pr. ct. quinin, 10 pr. ct. cinchonin, and 30 pr. ct. resin; the water amounted to 20 pr. ct. On precipitating 100 pts. of commercial quinoidin in solution with an alkali, the precipitate obtained weighed 69 grs. (*Chem. Gaz.* vi. 295, 296.)

This quinoidin is of the same composition and atomic weight as quinin, and seems to be the product of the action of heat on the latter, in the presence of an excess of sulphuric acid. Cinchonin yields it more readily than quinin, and hence, perhaps, the greater proportion of this product from barks in which the cinchonin predominates. It is insoluble in water, soluble in alcohol, and precipitated therefrom in dark brown flocculæ. It unites with the acids and forms soluble compounds, which are bitter, viscid, and uncrystallizable.

QUINOLIN. See LEUCOLIN.

QUIORIC ACID.

QUIORIC BITTER. } Syn. Knioric. Exists in calasaya and other quinin barks. A peculiar bitter, non-nitrogenous principle, soluble in alcohol and ether, and almost insoluble in water. According to Schnedderman, knioric acid and bitter are identical. (*Journ. für Prakt. Chem.* xxviii. p. 327.)

QUINOVIN. Obtained by Winckler from *Jean cinchona*, and found by that chemist to be identical with ARICIN.

R.

RACEMIC ACID. *Chem.* Syn. Acid of the Vosges, Paratartaric acid. Formula $C_8H_4O_{10} + 2 HO$. Accompanies tartaric in the juice of the grape, and is not only isomeric with it and of the same atomic weight, but produces a

RADISH ROOT.

series of salts analogous in composition, and in some instances isomorphous with the tartrates.

Crystallizes in oblique prisms with rhombic base, which effloresce in dry air, and lose 1 equiv. of water at 212° . Is soluble in 6 pts. of water at 60° , and thus differs from tartaric acid, from which it is further distinguished by its property of precipitating chloride of calcium, nitrate, and even sulphate of lime.

By distillation it yields products similar to those from TARTARIC ACID.

It is yet undecided whether this acid is mono- or bi-basic.

The double racemate of potassa and soda crystallizes in colorless, rhombic prisms, of composition $C_8H_6O_{12}$, KO, NaO, 6 HO.

RADEOLITE. See MESOTYPE.

RADICAL. See COMPOUND RADICAL.

RADIOGRAPHY. The art of imprinting by rays, first invented by Moser, of Königsburg. Prof. P. G. Page, of the U. S. Patent Office, repeated the experiments of the originator in manner as follows:—

A highly polished silver plate was placed at a very short distance (say one-thirtieth part of an inch) above an ornamental design upon the cover of a book, and allowed to remain in this condition in a dark place about eight hours. At the end of this time nothing was visible upon the plate, nor could any picture be perceived by breathing upon it. The plate was then iodized, as if for Daguerreotype impression, and then submitted to the vapor of mercury, when the whole picture appeared with distinctness. The design was a stamped vignette upon the cover of a book, enclosing the words "Year Book of Facts, 1842," all of which were legible upon the plate.

Images of seals and cameos were also obtained, perfect in the minutest details; and it was found, when the first condition of the plate was sufficiently prolonged, that simply breathing on the plate developed the picture while the moisture remained upon the plate; but that the impression remained permanent by submitting it to the vapor of mercury.

The picture may be produced by mercury, without the intervention of iodine, or even by iodine without the mercury. By iodizing the plate in the dark, and then exposing it to diffuse daylight, or still better to direct sunlight, the image appears, and is rendered permanent.

The most perfect pictures are produced by direct contact, and in the shortest time; while, as the distance increases between the plate and the object, the image becomes weak and diffused, and is finally lost entirely, when the distance is great.

RADISH ROOT. The root of the *Raphanus sativus*, used as an esculent. Herapath's analysis gives, as the constituents of 1000 grains of the fresh root,—

Water	959.742
Lignin.....	17.017
A nitrogenous substance, containing a little starch	2.043
Albumen	0.908
Extractive matter	2.261
Gum	4.299
Sugar	1.143
Purple red coloring matter	1.768

RAJA CLAVATA.

Fixed oil.....	0-401
Sinapin ?	0-037
Earthly phosphates and carbonates, with a little sulphate of lime.....	0-740
Acetates of potash and soda.....	0-223
Nitrates of potash and soda.....	5-169
Chlorides of potassium and sodium....	4-155
	999-116

And, upon incineration, 1000 grs. would yield 8-285 grs. of ash, which would be composed of—

Carbonate of soda.....	2-174
Carbonate of potash.....	2-252
Sulphate of soda.....	0-534
Chlorides of sodium and potassium	0-889
Carbonate of lime.....	0-571
Carbonate of magnesia.....	0-148
Sulphate of lime.....	0-011
Phosphate of lime.....	1-440
Phosphate of magnesia.....	0-114
Perphosphate of iron.....	0-011
Silica.....	0-022

8-166

(Chem. Gaz. v. 282.)

RAJA CLAVATA. Oil of. See **SKATE LIVER OIL.**

RAPE OIL. Syn. Oil of Naven. Is expressed from the seeds of the several species of the genus *Brassica*, belonging to the family *Cruciferae*. The *B. napus* yields 33, *B. Campestris* 39, *B. præcox* 30, *B. napobrassica* 33, and the *B. rapa* only 16 pr. ct.

Has a yellow color and peculiar smell, and is used for purposes of illumination. It contains 46 pr. ct. of solid fat, which congeals at 25°, and fuses at 45°.

The spec. grav. of the oil from the campestris is .9136, of that from the napus .9128.

RAPHILITE. Allied to **HORNBLende**.

RATOFFKIT. See **FLUOR SPAR.**

REALGAR. *Min.* Red orpiment, Red sulphuret of arsenic. Cryst. Oblique rhombic, cleaving perfectly parallel to main end plane, less perfect in other directions; also granular. H. = 1-5—2. G. = 3-54—3-64. Color and streak flame-red, bright orange; resinous; transparent, translucent; sectile, yielding to the nail, and with conchoidal fracture. Sublimes by heat in a closed tube unaltered, and in an open tube gives white, crystalline, arsenious acid; fuses on charcoal, burning with a yellowish white flame; soluble with difficulty in aqua regia, and changed to brown by potassa lye. Form. AsS_2 . It occurs in Hungary, Bohemia, Saxony, and the Hartz. See **Sulphuret of ARSENIC.**

REALGAR. *Chem.* Sulphuret of **ARSENIC.**

RED ANTIMONY. *Min.* Pyrantimonite; Rothspiesglaserz; Antimonblende. Crystalliz., Oblique rhombic, with perfect lateral cleavage. H. = 1—1-5. G. = 4-4—4-6. Cherry-red; adamantine; subtranslucent; sectile, with brownish red streak. It behaves like gray antimony. Form. $\text{SbO}_3 + 2\text{SbS}_3$. It occurs near Posing, Hungary; Freiberg, Saxony, &c.

RED CHALK.

RED HEMATITE.

RED IRON-ORE.

REDDLE.

} See **SPECULAR IRON.**

RESIN.

RED COBALT. See **COBALT BLOOM.**

RED COPPER-ORE. *Min.* Rothkupfererz; Tile-ore; Ziegelerz. Cryst. Regular; generally the 8-hedron, but also exhibiting combinations of most of the simple forms of the regular system. Also fibrous, granular. H. = 3-5—4. G. = 5-992. Deep blood-red, brownish red; adamantine, submetallic; subtransparent, subtranslucent; brittle with conchoidal fracture and brownish red streak. Heated on coal it blackens, then fuses, yielding a globule of copper; heated in the pincette it colors the flame green, and moistened with muriatic acid, blue. Soluble in nitric acid to a blue solution, in muriatic brownish, precipitable from the latter by water, as white subchloride; soluble in ammonia. Form. Cu_2O . Found in many copper mines. When mingled with a large proportion of silica and oxide of iron, it is tile-ore, of an ochrey-red and yellow color.

RED IRON VITRIOL. See **BOTRYOGEN.**

RED LEAD-ORE. See **CHROMATE OF LEAD.**

RED SILVER. See **RUBY SILVER.**

RED ZINC-ORE. *Min.* Cryst. Right rhombic. H. = 4—4-5. G. = 5-43—5-523. Dull orange, deep red, brownish red; vitreous; translucent, subtranslucent; brittle, with subconchoidal fracture and orange-yellow streak. Infusible; heated with soda on coal, it gives a coating of zinc, and with the fluxes shows manganese. Form. ZnO (MnO or Mn_2O_3), containing nearly 90 pr. ct. oxide of zinc. It occurs in great abundance at Franklin and Sterling, N. Jersey.

REFINING. *Tech.* The purification of substances: as refined sugar, refined cobalt, silver, gold, &c.

REFRACTION. *Min.* The refraction of light is sometimes, but rarely used in mineralogy. A crystal of Iceland spar (transparent calcareous spar) exhibits two images of a black point on white paper, in every direction except in that of the vertical axis, where the ordinary and extraordinary rays coincide. This is the axis of double refraction, of which there is but one in the quadratic and hexagonal systems; and two in the right and oblique rhombic, and triclinic systems. Crystals of the regular system have no axis of double refraction.

REGULUS. The term applied to *pure* metal, entirely free from combined and extraneous matter. The title originated with the alchemists, and was given to the metallic residuum left in their crucibles after the expulsion of volatile portions by fusion, under the supposition that it contained gold, the king of metals.

RENNET. The mucous membrane of the fourth stomach of the calf. Possesses the property of coagulating milk, which is due to the presence of pepsin. See **GASTRIC JUICE.**

RENSSELAERITE. See **AUGITE.**

RESIN. *Chem.* A natural constituent of plants, sometimes held in solution by essential oil (**BALSAMS**), and when in large proportion exuding through incisions made into the trees. If the amount is small, alcohol is used to extract it, and from its spirituous solution the resin may be precipitated by water. Some resins are called *soft*, in contradistinction to the *hard*, which retain but little or no volatile oil. Some resins are colorless, others yellow,

brown, red, or bluish green, but mostly translucent. They are generally mixtures of one or more resins, of different characteristics. None are soluble in water, but nearly all dissolve, either wholly or partially, in alcohol, ether, the essences, fat oils, and sulphuret of carbon. Some are entirely neutral, others have acid properties, but in a weak degree, though they form compounds with the alkalies, and run with metallic bases, and hence a means of distinguishing the two classes. In powder or fusion they become altered in composition by exposure. They dissolve in strong HCl and acetic acid, but are precipitated by water. The action of concentrated sulphuric acid changes them into artificial TANNIN. Nitric acid forms oxalic acid and a series of new products.

Owing to the analogy of the reactions of oxygen and oxidizing agents upon volatile oils and their resins, the latter are, by some chemists, considered as oxides of the former; but as it has been shown that the portion of hydrogen avidously seized upon by iodine, when in contact with the essence, is in a different state of combination from the remainder, it is most probable that the atmospheric oxygen removes this loosely-combined hydrogen, forming water, and that the removed hydrogen is also replaced by oxygen. "The water thus formed may either remain in combination with the new oxidized compound, or be separated. Hence, when an ESSENTIAL OIL is resinified by exposure, the composition of the resin must be equal to that of the oil, less a certain quantity of hydrogen, and plus a certain quantity of oxygen."

RETINALITE. *Min.* Probably a variety of serpentine.

RETINITE. *Min.* Retinasphalt. Several bituminous substances have been included under this name. They consist of from 50 to 90 pts. soluble in absolute alcohol, 10 to 40 pts. insoluble in the same, and more or less ashes. Johnston's examination of one from Bovey coal, in Devonshire, is the most complete. It gave 13 pr. ct. ash, consisting of alumina with some silica, 27½ organic matter, insoluble in alcohol, and 59 resin, soluble in alcohol. The latter is soluble in ether and alcohol, precipitable by alcohol from the former, by water from the latter; fusible at 250°, perfectly fluid at 320°; form. $C_{21}H_{14}O_3$; it combines with bases, and is termed retinic acid. See BERENGELITE, COPALITE, GUYAQUILLITE, MIDDLETONITE, PIAU-ZITE.

RETINYL. See RESIN.

RETORT. A glass vessel used in DISTILLATION. See figs. 45, 46, p. 523.

REVERBERATORY. See FURNACE.

RHÆDIC ACID. *Chem.* A constituent of the coloring principle of red poppy flowers, first obtained by Meier (*Buch. Rep.* xli. 235). It exists along with papaveric acid.

When pure is a shining, dark red, amorphous mass, inodorous, and of an acid taste. Soluble in cold water with a red color, and in cold, absolute alcohol, but insoluble in ether. Its salts are brownish, bluish gray, or violet, inodorous, mostly tasteless, amorphous, and all insoluble in absolute alcohol.

RHÆTIZITE. See KYANITE.

RHAMNIN. See PERSIAN BERRIES.

RHAPONTICIN. } See RHUBARB.
RHEIN. }

RHODEORETIN. See JALAP.

RHODIUM. *Chem.* A metal discovered by Wollaston in platinum sand, and most accurately investigated by Berzelius. *Prep.* See PLATINUM. The metal is difficult of fusion, but it may be obtained in small beads by throwing the oxide into fusing saltpeter. It is silver-white, hard and brittle, of spec. grav. about 11.0. Sym. R. Eq. 52 (or 651.96, O. = 100; 52.16, H. = 1, Berz.)

1. *Oxide of Rhodium, RO.* Obtained by ignition of the powdered metal to redness in the air; forms a black powder, which is again reduced by a higher heat. If a lower heat be continued it takes up more oxygen, but not sufficient to form the sesquioxide.

2. *Sesquioxide of R., R_2O_3 .* The hydrate, R_2O_3, HO , is obtained by igniting the powdered metal with potassa and a little saltpeter, washing with cold and then hot water, and a little muriatic acid; or by evaporating the double alkaline chloride with carbonated alkali, and washing with water. It is greenish gray or brown, and holds its water so firmly as to require ignition to obtain the dry oxide. It is reduced by hydrogen at common temperatures. Its salts are usually rose-red in acid solution; reducible by the metals; precipitable by chloride of tin, or colored yellow, if very dilute; precipitated by the fixed alkalies and their carbonates brownish red; by sulphuretted hydrogen or sulphammonium, brown by heat, and after some time, and not soluble in excess of sulphammonium; not precipitated by chloride of potassium or ammonium, or by cyanide of mercury.

3. *Sulphuret of R., RS,* is formed by heating the precipitated sesquisulphuret in carbonic acid, or by heating the chlor-rhod-ammonium with sulphur. It is bluish white, metallic, fusible, losing its sulphur by roasting. The precipitated *sesqui* is brown, soluble in nitric acid.

4. *Alloys.* Rhodium forms a brittle alloy with arsenic, from which the latter may be roasted off. It forms, with 3 pts. of bismuth, lead or copper alloys, soluble in aqua regia; with silver and with gold, malleable alloys, from which aqua regia does not extract rhodium. Equal parts rhodium and steel form a beautiful speculum metal, not tarnishing in the air; 1 R. with 50 to 100 steel, gives a tough alloy, which requires a higher heat for tempering than steel.

5. *Salts.* The hydrate is soluble in caustic potassa or soda with a yellow color, and forms a yellow precipitate after some time, with ammonia. a. The finely-powdered metal is mixed with an equal quantity of chloride of potassium or sodium, and chlorine passed over as long as it is absorbed; it is then extracted with water, filtered, precipitated by alcohol, and the chloride of potassium washed out with alcohol of 0.84. This washed precipitate is the double chloride of rhodium and potassium or sodium, both soluble in water and yielding red crystals, the former with the formula $2 KCl, R_2Cl_3 + 2 HO$, and the $3 NaCl, R_2Cl_3 + 18 HO$; the latter is soluble in 1½ pts. water, insoluble in alcohol.

b. If the salt a. be dissolved in water, and

RHODIUM GOLD.

RICE.

the potassa be precipitated by fluosilicic acid, a brown solution of the sesquichloride is obtained, soluble in strong muriatic acid with a yellow color.

c. When chlorine is passed over finely-divided rhodium, a rose-red, insoluble chloride is obtained, 2RCl , R_2Cl_3 . When decomposed by boiling potassa, and the precipitated hydrate of RO , R_2O_3 is obtained, from which muriatic acid extracts the sesquichloride and leaves violet chloride, RCl .

d. By fusing (below redness) powdered rhodium with glacial phosphoric acid, a solution of phosphate is obtained, brown when concentrated, yellow when dilute. The solution of the hydrated oxide in nitric acid is yellow. A double nitrate with soda is crystallizable.

e. By heating the sesquisulphuret with fuming nitric acid, the dark brown residue, sulphate of sesquioxide, is soluble in water; and by heating, it becomes black sulphate of protoxide, which is insoluble in water and acids. By mixing solutions of rhodochloride of potassium and sulphurous acid, a white powder is formed after some time, of the composition KO , $\text{SO}_3 + \text{R}_2\text{O}_3$, 3SO_3 . By fusing the metal or its oxide with bisulphate of potassa, in a covered crucible, a double sulphate is formed, which is extracted readily with hot, more slowly with cold water, and is perfectly decomposed by ignition with carbonated alkali, extraction with water, then with muriatic acid, which leaves all the oxide.

RHODIUM GOLD. *Min.* Gold containing variable quantities of rhodium, averaging 31 pr. ct. From Mexico.

RHODIZITE. *Min.* Cryst. Regular. H. above 6. Grayish or yellowish white; vitreous, splendid; translucent; pyroelectric; scarcely fusible on the edges; colors the flame green and red; yields no water in a closed tube; dissolves in fluxes to a clear glass; fuses with fluor spar to a clear glass, but does not show sulphuric acid by treatment with silica and soda; difficultly soluble in muriatic acid, showing much lime in the solution. It seems to be a lime-boracite. See **BORACITE**. It occurs on red tourmaline, from Sarapulsk and Schaitansk, Siberia.

RHODIZONIC ACID. $\text{C}_7\text{H}_3\text{O}_{10}$, or $\text{C}_7\text{H}_7 + 3\text{Aq}$. Obtained by passing a stream of dry carbonic oxide over potassium, and exposing the black, porous mass thus formed, to the air, and treating it afterwards with alcohol. The resulting solution is of a scarlet color, and contains rhodizanate of potassa = $\text{C}_7\text{O}_7 + 3\text{KO}$. Upon the addition of alcohol acidulated with oil of vitriol, decomposition takes place, sulphate of potassa precipitates, and rhodizonic acid remains in solution, and may be obtained in crystals by evaporation.

Prop. Forms colorless needles of an astringent taste, soluble in water, alcohol, and ether. It reddens litmus, and bears a heat of 212° without alteration. All its salts are red, and by boiling in water becomes altered into croconate and oxalate of potassa.

Croconic Acid. C_5O_4 , HO . Separated from the potassa salt by alcohol acidulated with sulphuric acid, which dissolves the croconic acid, while the sulphate of potassa precipitates. It crystallizes in small, brilliant, yellow prisms,

soluble in water, alcohol, and ether, and which bear 212° of heat without decomposing.

All of its salts are yellow. That of potassa crystallizes in six-sided prisms.

RHODOCHROSITE, RHODONITE. See **MANGANES SPAR**.

RHOMB SPAR. See **BITTER SPAR**.

RHUBARB. *Chem. Pharm.* The root of the several species of *Rheum*, varying in composition with the soil, climate, and mode of culture.

Ordinary rhubarb root, as found in commerce, contains, according to the analysis of Schlossberger and Döpping:—(*Liebig's Annalen*, i. p. 496.)

1. *Aporetin*. A brilliant black, resinous body, easily pulverizable when dry, and decomposable if heated, without fusing.

2. *Phaeoretin*. $\text{C}_{16}\text{H}_8\text{O}_9$. A yellowish brown powder, difficultly soluble in water and ether, but readily soluble in alcohol. Alkalies dissolve it with a deep red brown color, and the minerals acids reprecipitate it yellow.

3. *Erythreoretin*. $\text{C}_{19}\text{H}_9\text{O}_7$. A crystallized resin, soluble in ether and alcohol, and slightly soluble in water, imparting a faint yellow tinge. Gives a yellow powder, which volatilizes with only partial decomposition. Forms a brown red solution with strong (cold) sulphuric acid, from which it is precipitated in yellow floccule by water.

4. *Rhein*. Syn. Rheumin, Rhabarberic acid, Rhubarb yellow. Supposed to be the active principle of the plant. A yellow, granular, crystalline body, somewhat analogous to chrysophanic acid. Is tasteless, inodorous, insoluble in cold water, slightly soluble in hot water, more so in hot ether. The presence of sugar does not, as Jonas has asserted, increase the solvent power of water as to this substance. Hot alcohol of 863 is the most ready solvent. Strong nitric acid dissolves it with a yellow color; strong sulphuric with a splendid red tint; and alkalies with an intense red of great beauty. From its sulphated solution water precipitates yellow flakes.

In addition to the foregoing constituents there are chrysophanic acid, water, starch, sugar, pectin, tannin, gallic acid, oxalic, sulphuric, HCl , phosphoric, and carbonic acids, iron, lime, magnesia, potassa, and soda.

The *Caphopierite* (*Rhabarberin*), or rhubarb bitter of Pfaff, is a mixture of coloring, resinous matters and other components of the root; and *Rhoponticin*, announced as one of the constituents of the root, is only found in the European variety. It is in yellow, inodorous, tasteless crystals, soluble in large excess of absolute alcohol and boiling water, but insoluble in cold water, ether, and the volatile oils.

RHUS COTINUS. See **FRUIT**.

RICE. The highly nutritious grain of the *Oryza sativa*, an annual plant, cultivated extensively in South Carolina and Georgia. The hulled grain consists, according to Braconnot, of

Starch	85.07
Gluten	3.60
Gum	.71
Uncrystallizable sugar	.29
Fixed oil	.13
Lignin	4.80
Water	5.00
Salts	.40

RICINOLEIC ACID. See CASTOR OIL.

RIEMANNITE. See ALLOPHANE.

RIONITE. *Min.* Eulebrite, Selenquicksilberzink, Selenid of zinc. Massive. G. = 5.56. Red, metallic, and earthy. It is chiefly seleniuret of mercury and zinc; it gives the odor of selenium on coal or in an open tube, and sublimes mercury and selenium in a closed tube. From Culebras, Mexico. A gray specimen was mixed with selenium and perhaps sulphur, from the same locality.

RIPIDOLITE. See CHLORITE.

RIVULIN. The mucilaginous matter of a fresh water algæ, *Rivularia tubulosa*, consisting of microscopic, green globules; these caught upon a linen filter exhibit, under the microscope, a movement like infusory animals.

ROBINIA. See ROBINIC ACID.

ROBINIC ACID. *Chem.* A body of unknown properties, extracted by Reinsch in acicular crystals, from the root of the *Robinia*, wherein it exists as an ammoniacal combination, with sugar, fat, essential and fat oil, chlorophylle, wax, tannin, yellow coloring principle, mucilage, albumen, starch, salts, and an alkaloid not yet isolated. (*Jahr. für Prakt. Pharm.* xi. 423.)

ROCELLIC ACID. $C_{24}H_{23}O_6$. From the *Rocella tinctoria*, which contains also *Erythric acid*, $C_{34}H_{19}O_{15}$ (*Schunck*). Crystallizes in fine, white needles, fusible at 295°, soluble in ether, and forms salts. See LICHENS.

ROCELLININ. See LICHENS.

ROCHELLE SALT. The tartrate of soda and potassa. See TARTARIC ACID.

ROCK CORK. See ASBESTUS.

ROCK CRYSTAL. See QUARTZ.

ROCK MILK. A white, earthy, CALCAREOUS SPAR.

ROCK OIL and TAR. See PETROLEUM.

ROCKS. *Geol.* In its narrower signification it denotes the hard and stony portions of the crust of the globe, and in its wider embraces also the softer clays and sands. The latter, by lapse of time with other causes, hardens into true rocky masses. Rocks are generally composed of more than one simple mineral, except limestone, which is often nearly pure carbonate of lime. Some few are fused by volcanic action, but the greater part are formed from sands and clays by cementation with water holding lime, iron, silica, &c., in solution. As rocks are cemented masses, in like manner they are disintegrated by a mixed chemical and mechanical action,—a chemical decomposition of the simple minerals by atmospheric agents, water, air, and heat, and a mechanical breaking up by frost, and washing away by water. See GEOLOGY.

ROCK SALT. See COMMON SALT.

ROCK SOAP. A variety of BOLE.

RODOCHROME. *Min.* Massive, and in fine scales. H. = 3.5. G. = 2.668. Dark green; pearly; subtranslucent; streak reddish white. becomes grayish white by heat, yields water, and is scarcely fusible; dissolves in fluxes, showing chrome and silica, and with cobalt solution the blue of alumina. G. Rose compares it to a serpentine, containing chrome. From the Ural, between Kyshtinsk and Syssersk.

ROMANOVITE. See GARNET.

ROMEITE. *Min.* Cryst. Regular. Yellow,

and scratches glass. It is chiefly antimonite of lime, from St. Maveel, Piedmont, with the form. $4 CaO, 3 SbO_3$.

ROSACIC ACID. *Chem. Physiol.* Found by Proust in the red sediment of urine, from intermittent fever patients.

ROSELLITE. *Min.* Cryst. Right rhombic. H. = 3. Deep rose-red; vitreous; translucent; streak white. It resembles COBALT BLOOM in nearly all its properties except its crystallographic. From Schneeberg, Saxony.

ROSE QUARTZ. See QUARTZ.

ROSES, OIL OF. Syn. Attar, Otto of Roses.

A colorless or yellow essence, obtained by the distillation of rose leaves with water. It diffuses an intense odor. Spec. grav. 8.32 at 90°. Does not redden litmus, and is partially resinified by the slow action of iodine. Alcohol of .806 takes up $7\frac{1}{2}$ pts. at 58° in 1000, and 33 pts. at 72°. Water dissolves 1 in 1000 pts.

Its stearopten or solid portion (CH_2) crystallizes out below 60°. It is fusible at 95°, dissolves slightly in alcohol and readily in ether and essential oils. Is also soluble in potassa, acetic acid, and in sulphuric acid with a brown color, but is scarcely acted upon by HCl or nitric acids.

Its falsifications with other essences and fat oils may be detected, the first by not concreting in the cold, the latter by the greasy stain which they leave upon paper when heated.

ROSIN OIL. } *Chem. Tech.* Destructive dis-

ROSIN. } tillation transforms rosin (*Colophony*) into a large number of gaseous and liquid carbo-hydrogens. The three principal products, however, are a dry, resinous residuum, a volatile, yellow oil, and a very consistent fatty oil. The two latter pass over into the receiver, and consist of *Resinein* ($C_{20}H_{15}O$), *Retinaphtha* (C_7H_4), *Retinyl* (C_9H_6) in the first, and *Retinole* (C_9H_4) and *metanaphthalin* or *Retestérène*, of the composition of naphtha, in the latter or more oily part of the distillate.

The essential oil (*vive essence*) is a very fluid pyroelaine, of a yellow color and very pungent odor, and contains water, acetic acid, and pitch. When freed of these impurities by distillation over caustic lime, it is, according to Louyet, a preferable substitute for camphine or oil of turpentine, either as a burning fluid, or as a dryer and thinner of mixed paints. By allowing the molten resin to fall into a retort containing incandescent coke, the yield of this product will be augmented.

Resins are bleached by dissolving them, in contact with steam, in a weak, alkaline lye, continuing the direct application of steam, and precipitating by dilute acid.

ROSITE. *Min.* Rosellan. In grains. H. = 2.5. G. = 2.72. Red; subtransparent; foliated, shining fracture. It behaves like amphotelite, but is softer, more fusible, and fuses with an excess of soda. Form. $3 RO, 2 SiO_3 + 6 (Al_2O_3, SiO_3) + 6 HO$. From limestone, in Södermanland. See POLYARGITE.

ROSOLIC ACID. A body of unknown properties, found by Runge in coal tar.

RUBELLAN. See Hexagonal MICA.

RUBELLITE. See TOURMALIN.

RUBICELLE. See SPINELL.

RUBINIC ACID. See CATECHU.

RUBY. See SPINELL. Oriental Ruby. See CORUNDUM.

RUBY SILVER. *Min.* Dark red silver, Black silver, Dunkles Rothgültigerz. Light red silver, Proustite, Lichtes Rothgültigerz. Cryst. Hexagonal, usually the hemiforms, skalenohedron and its prism, terminated by an obtuse rhomb. Also granular. $H. = 2 - 2.5$. G. of the dark = $5.7 - 5.9$; of the light $5.422 - 5.56$. Color black and cochineal red, which last is the streak; metallic, adamantine; subtransparent, opaque; fracture conchoidal; sectile. Decrepitates by heat, fuses on coal, giving off sulphurous acid, and in the dark red, vapors of antimony, and leaving a globule of silver; the light red gives vapors of arsenic. The formula is $3 AgS, RS_3$, in which R is antimony in the dark red, and arsenic in the light. According to Zinken, some light red contains no arsenic. It is one of the most valuable ores of silver, and when pure contains 57 to 60 pr. ct. It occurs in many silver mines, Saxony, Hartz, Bohemia, Hungary, Norway, Spain, Mexico, California.

RUBY SULPHUR. See REALGAR.

RUE, OIL OF. *Chem.* $C_{28}H_{28}O_3$ (Will). The volatile essence of the *Ruta graveolens*. Is yellowish or greenish. Spec. grav. .837; boils at 425° to 438° ; density of vapor 7.69. Its solution in sulphuric acid is brown red, and water separates the oil unaltered.

Gerhardt's recent investigations (*Ann. de Chem. et de Phys.* 1848) show that it is composed mostly of an oxygenated oil, $C_{20}H_{20}O_2$, which behaves like the aldehyde of capric acid, and is converted by nitric acid either directly into capric acid, $C_{20}H_{20}O_4$, or into homologous acids, containing less carbon, the principal of which are the rutic and pelargonic acids.

Oil of rue has recently been formed artificially from cod liver and train oils (*Wagner, Chem. Gaz.* vii.), by mixing them with sulphuric acid, saturating with alkali or lime, and distilling.

RUFIN. *Chem.* By distilling phloridzin, a red body remains, which Mulder terms Rufin; and by the action of oil of vitriol on phloridzin, rufin-sulphuric acid is formed.

RUSOT. *Pharm.* The aqueous extract of the root and stem of the *Berberis lycium* of India. A pale yellow, uniform, pasty extract, soluble in water and alcohol. It is very bitter, and contains tannin. It is much used by the native practitioners as a febrifuge, and as a substitute, to a certain extent, for cinchona bark. (*Chem. Gaz.* i. 523.)

RUST. The oxidation of iron in moist air. It commonly contains sesquioxide of iron, carbonic acid, water, and ammonia.

RUTHENIUM. *Chem.* Surmised by Osann to exist in platinum sand; discovered and fully studied by Claus. Its *prep.*, see PLATINUM. Claus observes that ruthenium is to rhodium like iridium to platinum. It has a stronger affinity for oxygen than all the other platinoid metals, and hence, while it oxidizes by ignition in the air, the oxide is not reducible by heat alone. It tends to form a salt with potassa, the ruthenate, and hence its mode of extraction.

The hydrated sesquioxide, Ru_2O_3 , is obtained by precipitating the sesquichloride by alkali,

or the dry oxide by fusing the metal with salt-peter in a silver crucible. By extracting with water, ruthenate of potassa dissolves, and leaves some sesquioxide. If this solution be neutralized by nitric acid, binoxide, RuO_2 , is deposited, while oxygen escapes. The dry binoxide is obtained by heating the sulphuret, or bisulphate ($RuO_2, 2 SO_3$) to ignition. The hydrated binoxide is obtained by evaporating the chloride double salt, $KCl, RuCl_2$, with carbonate of soda to dryness, and washing out. The oxide, RuO , is obtained by igniting the dry chloride, $RuCl$, with carbonate of soda in carbonic acid, and extracting with water. When the metal is heated in the air, it forms an oxide like rhodium, RuO, Ru_2O_3 ; and by continuing the heat, blue sesquioxide is formed.

The sulphuret, Ru_2S_3 , is precipitated brownish yellow by sulphuretted hydrogen, from the chloride; and is rapidly soluble in nitric acid, of 1.22, to a reddish yellow solution of sulphate of sesquioxide. Ru is not perfectly precipitable by sulphohydrogen, but the remaining solution is bluish, probably from blue chloride.

When the metal is heated in chlorine, a little sesquichloride at first sublimes, and the black mass remaining is chloride, $RuCl$; insoluble in acids. When the oxide obtained by precipitating ruthenate of potassa by nitric acid is dissolved in muriatic acid and evaporated to dryness, soluble sesquichloride is obtained, Ru_2Cl_3 .

Double salts with potassium, sodium, and ammonium, are obtained by mixing them together; the former is crystallizable, insoluble in alcohol of 80 pr. ct.

When sesquisulphuret of ruthenium is treated with dilute nitric acid, a yellow solution of sulphate of binoxide is formed, $RuO_2, 2 SO_3$. (*Berz. Jahresb.* 1846-8.)

RUTILE. *Min.* Titanic ore, Crispite, Gallizinite, Lagenite. Cryst. Quadratic, prisms terminated by 8-hedra, and often twinned by turning 180° on an 8-hedral plane. $H. = 6 - 6.5$. G. = $4.18 - 4.249$. Brownish red to dark brown; metallic, adamantine; subtransparent, opaque; subbrittle, with subconchoidal and uneven fracture, and light brown streak.

Infusible and unaltered by heat; gives with borax in the outer flame a greenish, in the inner a violet glass; in mic. salt, in the inner flame, a red glass (from titaniferous iron), and sometimes with the addition of tin, a blue or violet glass; fuses with soda, with effervescence to a bead, and sometimes shows manganese; it usually shows tin, when treated as directed with carbonate of soda, p. 350. It is titanic acid, TiO_2 , with more or less oxide of iron, often less than 2 pr. ct.

Rutile occurs in primary rocks, and in older limestones, in many localities. Very large crystals have been found in Lancaster Co., Pennsylvania.

RUTILIN. *Chem.* Is the name given by Braconnot to the red substance produced by solution of salicin in oil of vitriol, but it is Rufin-sulphuric acid.

RUTIN. *Chem.* A principle extracted from the leaves of the *Ruta graveolens*, by alcohol, evaporation, and treatment with ether, in which rutin is insoluble. It appears to have an acid

character. Bornträger examined a principle from the same root, which he termed *Rutic acid*. It is a pale, greenish, crystalline powder, scarcely soluble in water, soluble in alcohol, giving orange-yellow compounds with alkali, bright yellow with lead salts. Its form. is $C_{12}H_6O_6$, 2 HO, which 2 HO is replaced by one of PbO in the lead salt. (*Berz. Jahresb.* 1846.)

RYACOLITE. *Min.* Cryst. Oblique rhombic, in glassy crystals. $H. = 6$. $G. = 2.55 - 2.68$. Color grayish white and colorless; vitreous, pearly; transparent; fracture conchoidal. It behaves like FELDSPAR. Form. see FELDSPATHIC MINERALS. From the Dolomite of Lomma, and the Eifel.

RYE. *Syn. Secale cereale.* The grains contain—

24.4 pr. ct. of husks or bran,
65.6 “ “ “ flour,
10.2 “ “ “ water.

The flour consists of—

61.00 pr. ct. of starch,
9.48 “ “ “ gluten,
3.28 “ “ “ albumen,
3.28 “ “ “ uncrystallizable sugar,
11.09 “ “ “ gum,
6.38 “ “ “ lignin.

Fresenius' and Will's analyses of the ashes of the straw and grain gave, as the constituents:—

	Straw.	Grain.
Potassa.....	17.19	11.43
Soda.....	—	18.89
Magnesia.....	2.41	10.57
Lime.....	9.06	7.05
Phosphoric acid.....	3.82	51.81
Sulphuric acid.....	0.83	0.51
Silica.....	64.50	0.69
Peroxide of iron.....	1.36	1.90
Chloride of sodium.....	0.57	—
Chloride of potassium.....	0.26	—

S.

SABADILLA. *Chem. Pharm.* *Syn.* Cevadilla. The seeds of the *Veratrum sabadilla*, containing fatty and yellow coloring matters, gum, wax, lignin, saline matters, and silica, gallate of VERATRIN, *Cevadic* or *Sabadillic acid*, *Sabadilla* and veratric acid.

Cevadic acid. See HELLEBORE.

Sabadilla. A white, crystallizable acid base, readily soluble in hot water and alcohol, but insoluble in ether.

Veratric acid. Allied to the volatile, fatty acids. Forms fusible and volatilizable, colorless crystals. Is soluble in alcohol, less so in water, and insoluble in ether. (*Merck.*) Formula of the hydrated acid $C_{18}H_9O_7$, HO. (*Schrötter.*) Its salts are mostly soluble.

SABADILLIC ACID. See Cevadic acid, in HELLEBORE.

SACCHARIC ACID. See SUGAR.

SACCHARITE. *Min.* Granular, white. $G. = 2.668$. Infusible alone, and difficultly so with soda; soluble to clear glasses with borax and mic. salt, leaving a skeleton of silica in the latter. Form. $2 [3 RO, 2 SiO_3 + 3 (Al_2O_3, 2 SiO_3)] + 3 HO$. $RO = NaO, CaO, MgO, KO$. The first part of the formula is that of andesin

and of leucite. It occurs near Frankenstein, Silesia.

SACCHULMIN. See SUGAR.

SAFFLOWER. See CARTHAMUS.

SAFFRON. The flower of the *Crocus sativus*, a plant indigenous to Asia Minor, but cultivated in Europe. Spanish saffron is the most preferable. The *Crocus orientalis* is one of several species about which but little is known. According to Aschoff, the *Crocus sativus* is composed of—

Volatile Oil.....	1.4
Wax.....	4.0
Polychroite.....	52.0
Gum.....	10.4
Woody fibre.....	19.0
Water.....	10.0
Balsamic matter, soluble in ether and alcohol.....	2.0
	98.8

The oil is bitter, slightly soluble in water but of greater specific gravity, and by age becomes lighter, and solidifies into a white mass.

Polychroite. *Syn.* Saffron yellow. The coloring matter of the plant is so termed, from *πολύς*, many, and *χρῶμα*, color, expressive of its susceptibility of numerous changes. When pure, it is soluble in alcohol and the oils, and slightly so in water and ether. Its color is changed by the acids, and entirely bleached by the hypochlorites. (*Henry.*)

As saffron is often adulterated, Mulder recommends concentrated sulphuric acid as the most certain test of purity, for it immediately turns the color of pure saffron to blue. The leaves of the *Crocus vernus*, a frequent adulteration, are changed to a dark green.

Winckler and Gruner detect safflower and marigold petals by means of a solution of silver or perchloride of iron, which renders their solutions opaque, and ultimately precipitates them, while an infusion of true saffron is not altered by either reagent.

SAGAPENUM. *Chem. Pharm.* The gum resin or concrete juice of an unknown species of *Ferula*, belonging to the family of the *Umbelliferae*, growing in Persia. It consists of resin, volatile oil, gum, mucilage, water, salts, and foreign matters.

Volatile oil. Pale yellow, very fluid and lighter than water, with garlicky odor and bitter taste. It appears to consist of two oils.

Resin. A mixture of two resins differing in characteristics: one brittle, inodorous, and tasteless, soluble in alcohol, but insoluble in ether and the oils; the other soft and bitter, soluble in both alcohol and ether.

SAGE. The leaves of the *Salvia officinalis* yield oil by distillation. Rochleder found in an 8 year old oil that the essence passing over at 263° is $C_{12}H_5O$, that passing over at 212° is $C_{18}H_{15}O_2$. From a two year old oil, the essence distilling at about 280° , is of the same formula as the last; that passing at 300° , is $C_{12}H_{10}O$. The results of his analyses show that they are oxides of a radical which is the multiple of C_6H_5 .

SAGENITE. See RUTILE.

SAGO. *Pharm.* Used as a nutritive article of diet. The prepared fecula of several spe-

cies of palm, among which are the *Sagus rumphii*, *Phoenix farinifera*, and *Sagus genuina*. It is extracted from the pith.

Pearl Sago is formed by granulating the meal, and when in large and brown grains, is called *Common Sago*. The latter is insoluble in cold water, but forms a gelatinous solution after long boiling. The pearl variety is partially dissolved by cold water. In a chemical view, it has the properties of starch, and is sometimes adulterated with potato starch.

SAHLITE. See AUGITE.

SAL ALEMBROTH. See ALEMBROTH.

SAL AMMONIAC. Muriate of AMMONIA.

SALAMMONIAC. *Min. Ger.* Salmiak. Cryst. Regular; also stalactitic and in crusts. $H. = 1.5 - 2$. $G. = 1.528$. White, sometimes yellowish; vitreous, translucent; taste saline, pungent; inodorous. Readily soluble in water; volatilizing by heat; mixed with lime and moistened, it gives a strong odor of ammonia. It is essentially muriate of ammonia, NH_4Cl , with some sulphate of ammonia. It occurs in fissures near volcanoes, and about coal-mines.

SALICIN. *Chem.* Discovered by Le Roux and Buchner in the bark of several species of willow (*Salix*) and of poplar. Wöhler recently found it in castor.

Prop. Merck's process is to add litharge to the boiling concentrated decoction of the bark, until it becomes colorless. This removes the gum, tannin, and extractive matter. The dissolved oxide of lead is then to be removed, first by sulphuric acid, and subsequently by sulphuret of barium (not in excess). Filter and evaporate. The crystals thus obtained by recrystallization and treatment with bone-black, become perfectly white.

Prop. $C_{26}H_{18}O_{14} = C_{14}H_8O_4 + C_{12}H_{10}O_{10}$. Crystallizes in transparent, inodorous, silky needles or laminae, of a bitter taste, permanent in the air, and without action upon vegetable colors. Heated above 212° it loses weight, melts at 230° , and at a higher heat becomes yellow and resinous in appearance, and decomposes. Is soluble in alcohol and hot water, partially in cold water, but insoluble in ether and the oils. Neither tannin, gelatin, nor subacetate of lead precipitate it.

When warmed to 104° with synaptase, it is resolved, according to Piria, into its two constituents, grape sugar ($C_{12}H_{22}O_{11}$) and a new body, *Saligenin*. The latter may be separated from the mixture by ether, which dissolves it without touching the sugar, and yields it in crystals by spontaneous evaporation. The product of the salicylic or gaultheric FERMENTATION forms a series analogous to the benzoic.

Saligenin. Formula of the crystallized acid, $C_{14}H_8O_4 = C_{14}H_6O_2 \cdot 2HO$. In brilliant, pearly, rhomboidal tables, greasy to the touch, and by spontaneous evaporation solidifying into an opaque mass. Is soluble in alcohol and ether, more readily in hot than cold water, and its solution gives a deep indigo color with aqueous solutions of salts of sesquioxide of iron. Does not alter on exposure to air, melts at 180° , volatilizes at 212° , and by continued action of heat is changed into *Saliretin*, water and hydruret of salicyl. The dilute acids also transform it into saliretin.

Dilute nitric acid colors it red, as also does

sulphuric acid, but more intensely. Potassa appears to combine with it, but potassa in fusion disengages hydrogen, and forms salicylic acid. Caustic ammonia dissolves it, and the liquid on exposure to air becomes green, but loses color when heated, and resumes it on cooling. According to Piria, the only two products of the oxidation of saligenin are water and hydruret of salicyl.

Saliretin. $C_{14}H_6O_2 + 2HO$. Formed by the action of dilute SO_3 and HCl acids upon salicin or saligenin. A resinous substance, insoluble in water and in ammonia, soluble in alcohol, ether, and concentrated acetic acid. From its alkaline solutions the acids precipitate it as a white, gelatinous precipitate.

Action of Chlorine upon Salicin. The action of this gas generates three crystallizable compounds: *Chlorosalicin*, $C_{26} \left\{ \begin{smallmatrix} H_{17} \\ Cl \end{smallmatrix} \right\} O_{14}$, *Bichloro-*

salicin, $C_{26} \left\{ \begin{smallmatrix} H_{16} \\ Cl_2 \end{smallmatrix} \right\} O_{14}$, and *Perchlorosalicin*, $C_{26} \left\{ \begin{smallmatrix} H_{15} \\ Cl_3 \end{smallmatrix} \right\} O_{14}$.

Action of Nitric acid. When the acid is strong, salicin is converted into oxalic and nitropicric acids; but if dilute, anilotic and anilic acids, helicin and heliceidin are previously formed.

Helicin. Formula of the anhydrous, $C_{26}H_{18}O_{14} = C_{12}H_{10}O_{10} + C_{14}H_8O_4$. A neutral body, crystallizing in fine white needles, and giving with chlorine *Chlorohelicin*, and with bromine *Bromohelicin*.

Helicin is soluble in hot water and alcohol, but insoluble in ether. In crystals it contains 3 equivs. of water, which are lost at 212° .

Heliceidin. Obtained by the action of nitric acid of spec. grav. 1.08, upon salicin. A crystalline compound, composed of $C_{52}H_{34}O_{28}$ (Piria), or 2 equivs. of sugar, 1 of hydruret of salicyl, and 1 equiv. of saligenin.

Action of Sulphuric acid.—Rutilin. A dark brown, brittle substance, tasteless, insoluble in water and alcohol. Strong acids color it deep red, and alkalies violet. (*Bracconot.*) The deep red coloring which cold sulphuric acid imparts to salicin, serves to detect its presence in barks containing it. The red coloring matter thus formed, when precipitated, and freed of sulphuric acid, by water, is soluble in that liquid.

SALICOR. The ash of the *Salicornia annua*, a plant cultivated on the French coast of the Mediterranean, for the manufacture of soda. It contains 12 to 15 pr. ct. of carbonate.

SALICYL. *Chem.* Formula, $C_{14}H_5O_4$. The hypothetical radical of a series of compounds analogous to the benzoic, and so called from salicin, the origin of the salicylic products. It has also been found in the GAULTHERIA PRO-CUMBENS, as salicylate of methier. Pagenstecher likewise obtained its hydruret by distilling the flowers of meadow sweet (*Spirea ulmaria*); and Proctor, Jr. considers its methier formed by water in the bark of *Betula lenta*. In a separate state it has not yet been isolated, but the identity of the composition of its hydruret and that of crystallized benzoic acid, together with their similarity in behavior to chlorine and caustic alkalies, led Dumas to consider this radical a higher degree of oxidation of benzöyl.

Hydruret of Salicyl. Syn. Hydruret of Spiroyl (*Löwig*), Salicylous acid, Spiroylous acid. $C_{14}H_5O_4 + H = SaH$. Exists in nature as above mentioned, and may be prepared by oxidizing salicin with chromic acid in manner as follows:—Dissolve 1 pt. of salicin in 10 of water, add 1 pt. of bichromate of potassa, $2\frac{1}{2}$ pts. oil of vitriol, and 10 additional parts of water, and, after the mixture has calmed, distil over a moderate fire. The distillate contains water and hydruret. The latter separates as an oleaginous stratum of a reddish color, and may be purified by digestion first with water, then with chlorcalcium, and subsequently, after decantation, by distillation.

Prop. When pure it is a colorless, inflammable, oily liquid, which reddens on exposure to air, and emits the odor of bitter almonds. It has a burning taste, and colors the skin yellow. Spec. grav. 1.93 at 56° . Boils at 380° ; density of vapor 4276; solidifies at -4° . Is very soluble in alcohol and ether, less so in water. Its solution reddens litmus, and then bleaches it. Concentrated sulphuric acid decomposes it. When heated with potassa in excess, hydrogen is evolved, and salicylic acid formed.

It is isomeric with benzoic acid, but does not, according to Wöhler, become hippuric acid by transit through the urine.

Its compounds with the bases are definite salts (salicylurets), of the general formula SaR , that is, viewing it as an hydrogen acid with the reaction as follows, $SaH + RO = SaR + HO$. But if considered as a hydrated oxygen acid, its salts are termed salicylites, and the reaction on the base is according to the hydratic theory of acids, $C_{14}H_5O_3, HO + RO = C_{14}H_5O_3, RO + HO$.

Potassa compounds. The hydruret of salicyl forms two salts with potassa, the *salicylite*, $C_{14}H_5O_3, KO, 2 HO$, in golden-yellow crystals, soluble in water, and *bisalicylite*, $C_{14}H_5O_3, KO, C_{14}H_6O_4$, in colorless, acicular crystals, less alterable than the former.

When the first-mentioned salt is exposed to air it becomes green, and ultimately black, by transformation into acetate of potassa and a black powder, melanic acid ($C_{10}H_4O_5$), which unites with bases. (*Piria*.)

Ammonia compounds. There are two,—1. *Salicylite of ammonia*, $C_{14}H_5O_3, NH_3, HO$ (*Löwig*), a yellow, crystalline mass, soluble in hot alcohol, and crystallizable therefrom in yellow needles, which blacken by absorption of moisture, and decompose; and 2. *Salicylimide* or *Salhydramide*, $C_{14}H_5O_2N_2$. Crystallizes in brilliant yellow prisms, insoluble in water, and soluble in large excess of alcohol.

Copper compounds. The salicylite of copper, $C_{14}H_5O_3, CuO$, is a very light, green powder, insoluble in water and in alcohol. By distillation it yields *Parasalicyl*, $C_{14}H_5O_3$ (*Ettling*), which crystallizes in prisms soluble in alcohol and in ether, but insoluble in water. They melt at 248° , and sublime at 356° .

Salicylic acid. Piria first obtained it by heating hydruret of salicyl with caustic potassa. It exists with oxide of methyl, in the oil of *GAULTHERIA PROCUMBENS*, from which it is obtained by potassa, and may be made, by heating salicin with fused potassa. Delalandes has recently procured it by the ac-

tion of potassa on COUMARIN, and Cahours found it, among other products, in the distillate of a mixture of indigo and potassa with sulphuric acid.

Prop. $C_{14}H_6O_6 = C_{12}H_6O_2 + C_2O_4$. Sublimes in crystals soluble in alcohol, ether, and hot water. Reddens litmus, and decomposes carbonates. By rapid distillation over lime, is changed into carbonic and phenic acids. The persalts of iron impart an inky color to its aqueous solution. The salts are generally crystallizable.

When acted on by nitric acid, *Nitrosalicylic*, *Carbazotic* (see INDIGO), and CARBOLIC ACIDS are formed.

Chloride of Salicyl. Syn. Chlorosalicylic acid, Chloride of Spiroyle. Formed by the action of dry chlorine upon anhydrous hydruret of salicyl. Crystallizes in pale yellow, rhombic tables, of a peculiar aromatic odor. Volatilizes without decomposition, and burns with a green flame. Dissolves in alcohol and ether, but is insoluble in water. It combines with the alkalies, and is separated from them unchanged, by acids. Ammoniacal gas converts it into *Chlorosalicylimide*, a deep yellow mass, insoluble in cold water, and decomposed by hot water, acids, and alkalies.

Methosalicylic ether. (Salicylate of Mether.) $C_{14}H_5O_3, C_2H_5O$. See *GAULTHERIA PROCUMBENS*.

SALICYLIMIDE. See **SALICYL**.

SALIFIABLE BASE. *Chem.* A term belonging to any body capable of uniting definitely with an acid or a salt, to form a salt. See **SALTS**.

SALIGENIN. } See **SALICIN**.
SALIRETIN. }

SALINE. *Min.* A substance having the taste of common salt, saltpeter, &c. It may be saline and cooling, as saltpeter; or saline and styptic, as copperas; or saline and pungent, as salammoniac. In the arts, a saline is a salt spring, or one containing common salt as its most important ingredient. See **WATER**.

SALIVA. *Chem. Physiol.* The transparent, slightly-viscid fluid secreted by the parotid, submaxillary, and sublingual glands, and conveyed from them by Steno's and other ducts into the mouth, where it becomes mixed with the buccal mucus.

Dr. S. Wright's analysis (*Chem. Gaz.* iv. 242) of healthy saliva gave, as its composition,—

Water	988.10
Ptyalin	1.80
Fatty acid	0.50
Chlorides of sodium and potassium ..	1.40
Albumen, with soda	0.90
Phosphate of lime	0.60
Albuminate of soda	0.80
Lactates of potassa and soda	0.70
Sulphocyanide of potassium	0.90
Soda	0.50
Mucus, with ptyalin	2.60

Ptyalin. When dry, is a brittle substance, of a sickly taste, without color, and transparent. Is soluble in water, but insoluble in alcohol and ether.

According to Mialhe and Lassaigne, a material is obtained from saliva by filtration, precipitation by alcohol, washing, and drying at

from 100° to 120°, which acts similarly to Diastase, changing boiled starch into sugar at from 100° to 150°, but is almost without action upon raw starch. Lassaigne has observed the same properties in pancreatic juice, but it is destroyed by a temperature of 212°.

SAL MIRABILE. Sulphate of SODA.

SAL PERLATUM. Phosphate of SODA.

SAL PRUNELLA. Fused Nitrate of POTASSA.

SALSEPARIN. See SARSAPARILLA.

SALT. *Chem. Ger. Salz. Fr. Sel.* The simplest definition of a salt would be, "a compound of an acid with a base," were it not that the very type of all salts—common salt—consist of a metal and an electronegative element, neither of the two elements being either acid or base. Thus, sulphate of soda, NaO, SO_4 , is a salt composed of the base soda, NaO , and the acid sulphuric, SO_3 ; so that both acid and base, containing one element in common, oxygen, the salt is composed of three elements, sodium, Na, sulphur, S, and oxygen, O. Now common salt, NaCl , consists of but two elements, chlorine and sodium. It is true that by dissolving common salt in water, it might be regarded as hydrochlorate of soda; thus, $\text{NaCl} + \text{HO} = \text{NaO}, \text{HCl}$, which therefore brings it under the above definition of "an acid with a base." But even in this case, the acid is very different from the oxygen acids, and the salt would then be composed of four elements. There are, however, other sufficient objections against considering such salts as hydrochlorates (as the insolubility of chloride of silver in water), and they are more properly regarded as solutions of chlorides in water. It is then evident that we have two classes of salts, those consisting of an acid and a base, and those consisting of two elements, a metal and a halogen body, such as chlorine. The former are termed *amphid salts*, and the latter *haloid salts*.

Again, if we pass sulphohydrogen gas through a solution of arseniate of potassa, $2 \text{KO}, \text{AsO}_5$, and evaporate the yellow solution, a yellow crystalline mass is obtained, having all the characters of a salt; but analysis shows it to be $2 \text{KS}, \text{AsS}_5$; that is, each equivalent of oxygen in the former is now replaced by an equivalent of sulphur. The 2KS acts the part of a base, and AsS_5 the part of an acid. The latter is a sulpho-salt. In like manner we have seleno- and telluro-salts, but they have not been minutely studied. Amphid salts then consist of an acid and a base, but both of these have either oxygen, sulphur, selenium, or tellurium common to them, and give as many divisions of amphid salts. However, only oxy-salts and sulpho-salts are usually mentioned. Hence the above oxy-salt is called arseniate of potassa, and its corresponding sulpho-salt sulpharseniate of potassium; but to distinguish the former with more precision, it may be termed oxyarseniate. The base is termed an oxy or sulphobase, and the acid an oxyacid or sulphacid.

We must still further extend the idea of salts to certain bodies containing a compound, which acts the part of an element. Thus ammonia, NH_3 , with one of water, HO , unites with sulphuric acid to form a salt analogous to, and isomorphous with sulphate of potassa. If their formulas be compared, KO, SO_3 and $\text{NH}_4\text{O}, \text{SO}_3$, we observe at once that NH_4 acts the part of the metal, K, potassium, and in fact it is called ammonium. Its chlorhaloid salt is $\text{NH}_3 + \text{HCl} = \text{NH}_4\text{Cl}$, which is similar to chloride of potassium, KCl . As ammonium, NH_4 , acts like a metal, so cyanogen, $\text{Cy} = \text{NC}_2$, acts like the halogens, chlorine, bromine, &c., and the cyanide and chloride of potassium are written KCy and KCl . When we speak, therefore, of a salt consisting of two or three elements, we must extend this notion to embrace compounds acting like elements.

Salts are either *neutral*, *acid*, or *basic*. If to a solution of potassa or soda sulphuric or muriatic acid be gradually added, a point arrives when the solution has neither an alkaline nor acid taste, when it ceases to redden turmeric or litmus paper. A neutral salt is formed, and in this case it consists of one equivalent of acid and one of base. If the acid be feeble, as carbonic, the salt it forms with an alkali will have a strong alkaline reaction; and if the base be feeble and the acid a strong one, as the sulphuric, the salt will test acid. Still it is called a neutral salt, if it consist of one equiv. of acid and one equiv. of a protoxide base. The general definition of a neutral amphid salt is, that it consists of one equiv. of base with as many equivs. of acid as there are equivs. of oxygen (or sulphur) in the base. Thus, FeO, SO_3 is neutral sulphate of iron (meaning protoxide of iron), and $\text{Fe}_2\text{O}_3, 3 \text{SO}_3$ is neutral persulphate of iron (meaning sulphate of peroxide). Neutral haloid salts consist of as many equivs. of metal and the halogen body, as there are equivs. of metal and oxygen in the corresponding oxide; thus, chloride of iron is FeCl , and perchloride of iron Fe_2Cl_3 .

Acid amphid salts contain more equivs. of acid than there are in the neutral salts, usually $1\frac{1}{2}$, 2, 3, or 4 times as many. The most common are those containing twice as much acid as the neutral salt. Thus, sulphate of potassa is KO, SO_3 , the acid or bisulphate $\text{KO}, 2 \text{SO}_3$. Acid haloid salts are compounds of a haloid salt, with a hydracid. Basic salts have more base than the neutral salt, and that usually in a simple ratio, as $\frac{1}{2}$, $\frac{2}{3}$, $\frac{1}{3}$, &c. of base, compared with that in the neutral salt. The silicates of the mineral kingdom present the greatest variety of combination of any other acid, and a table is subjoined to show the nomenclature. RO and R_2O_3 represent protoxide and sesquioxide bases. The first two columns of figures represent the proportions between the equivs. of oxygen in the base and acid, the first in the base, the second in the acid:—

Acid Silicates.

1	:	12	Quadrilicates	$\text{RO}, 4 \text{SiO}_3$	or	$\text{R}_2\text{O}_3, 12 \text{SiO}_3$
1	:	9	Trisilicates	$\text{RO}, 3 \text{SiO}_3$	"	$\text{R}_2\text{O}_3, 9 \text{SiO}_3$
1	:	6	Bisilicates	$\text{RO}, 2 \text{SiO}_3$	"	$\text{R}_2\text{O}_3, 6 \text{SiO}_3$
1	:	$4\frac{1}{2}$	Sesquisilicates	$2 \text{RO}, 3 \text{SiO}_3$	"	$2 \text{R}_2\text{O}_3, 9 \text{SiO}_3$
1	:	4	$\frac{2}{3}$ silicates	$3 \text{RO}, 4 \text{SiO}_3$	"	$\text{B}_2\text{O}_3, 4 \text{SiO}_3$

1	:	3	Neutral Silicates	RO, SiO_3	or	$\text{R}_2\text{O}_3, 3 \text{SiO}_3$
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Basic Silicates.

1	:	2	$\frac{2}{3}$	silicates (or $\frac{1}{2}$ -basic)	3 RO, 2 SiO ₃	or	R ₂ O ₃ , 2 SiO ₃
1	:	1 $\frac{1}{2}$	$\frac{1}{2}$	silicates (or unibasic)	2 RO, SiO ₃	"	2 R ₂ O ₃ , 3 SiO ₃
1	:	1	$\frac{1}{3}$	silicates (or bibasic)	3 RO, SiO ₃	"	R ₂ O ₃ , SiO ₃
1 $\frac{1}{2}$	:	1	$\frac{1}{4}$	silicates (or tribasic)	4 RO, SiO ₃	"	4 R ₂ O ₃ , 3 SiO ₃
1 $\frac{1}{2}$	:	1	$\frac{2}{9}$	silicates (or 3 $\frac{1}{2}$ -basic)	9 RO, 2 SiO ₃	"	3 R ₂ O ₃ , 2 SiO ₃
2	:	1	$\frac{1}{5}$	silicates (or 5-basic)	6 RO, SiO ₃	"	2 R ₂ O ₃ , SiO ₃
3	:	1	$\frac{1}{8}$	silicates (or 8-basic)	9 RO, SiO ₃	"	3 R ₂ O ₃ , SiO ₃

Basic haloid salts are composed of the haloid salt with the oxide of the same metal, as the compound oxide and chloride of lead, PbCl + PbO; they are sometimes termed oxychlorides. 2 equivs. of the haloid and 1 equiv. oxide, is $\frac{1}{2}$ -basic; 1 equiv. to 1 equiv. oxide, is unibasic; 1 to 2, bibasic, &c. Both haloid and amphot neutral salts produce basic salts by union with sulphuret, phosphuret, nitruet, and amiduret of the metal.

Two or more salts may combine with each other, producing double and triple salts. They are usually composed of one acid and two bases, and more rarely of one base and two acids. Thus, alum has the formula KO, SO₃ + Al₂O₃, 3 SO₃ + 24 HO. Haloid salts may also be doubled, in which case the same halogen is usually common to both, as chloride of copper and potassium, KCl, CuCl; more rarely the metal is the same, and the halogen different, as chlorofluoride of lead, PbF, PbCl. There are a few rather anomalous double salts, such as the mineral leadhillite, a sulphate and carbonate of lead, 2 (PbO, CO₂) + PbO, SO₃; the mineral corneous lead, also made artificially, PbCl + PbO, CO₂. There are but a few triple salts.

Salts are of very different solubility, and no law has yet been found by which we can determine *a priori* either the solubility of a salt at all, or the amount of that solubility. When water, which is the usual solvent, ceases to dissolve any more of a salt at a certain temperature, it is said to be saturated at that temperature. Most salts increase in solubility with the increasing temperature of the water; some in a greater ratio than the increase of heat, as nitrate of potassa and of baryta, and chlorate of potassa; others with a uniform increase, as sulphate of potassa and the chlorides of potassium and barium. Common salt dissolves equally at all observed temperatures. Some salts, as citrate of lime, basic borate of magnesia, and hydrate of lime, are more soluble in cold than in hot water. Sulphate of soda, Glauber's salt, increases in solubility to 91°, and then diminishes at a higher heat, so that a portion of it precipitates.

Some salts crystallize without combining water, such as nitrate of potassa, chloride of sodium, and most of the very insoluble precipitated salts, as sulphate of baryta, chloride of silver. The salts of potassium and silver are more frequently anhydrous, those of soda usually hydrous; but no law has yet been evolved on this point. Most salts take up water of crystallization, and always in equivalent proportions; but the number of equivalents is very different for different salts. A few take up less than 1 equiv. water for 1 equiv. of the salt, but the most general proportion is 1 equiv. salt to from 1 to 7 equivs. water. Some have, however, 8, 10, and 25 equivs. water. It is

somewhat remarkable, that many of the salts of soda contain 10 equivs. water, as the carbonate, biphosphate, sulphate, pyrophosphate, and iodate; the common phosphate has 25 equivs. water.

SALT OF LEMONS. Binoxalate of potassa. See OXALIC ACID.

SALT OF SATURN. ACETATE OF LEAD.

SALT OF SORREL. Binoxalate of POTASSA.

SALT OF TARTAR. Purified and granulated Carbonate of POTASSA.

SALTPETER. *Chem.* Nitrate of POTASSA.

SALTPETER. *Min.* See NITRE.

SAND. *Geol.* Sand generally consists of particles of quartz (silica), but there is also granitic sand, containing particles of feldspar as well as quartz, where it has not been long enough exposed to meteoric agents to decompose the feldspar. Sand usually consists of grains more or less rounded, but they are sometimes angular, and are then preferable for mortar. Sand generally contains some oxide or silicate of iron, but that which is most free from such impurities is required for the manufacture of glass.

SANDARAC. *Syn.* Juniper resin. The odorant resin of the *Thuja articulata*, entirely soluble in ether and absolute alcohol, and consisting, according to Unverdorben, of three resins differing as to solubility in alcohol, ether, and spirits of turpentine. The *Sandaracin* of Geise is a mixture of two of these resins.

SANDARACA. See REALGAR.

SAND BATH. See BATHS.

SANDERS. The wood of the *Pterocarpus santalinus*, distinguished from Brazil wood by not imparting its color to water.

Santalin (*Chem. Gaz.* ii. 371). The resinous matter extracted by alcohol, and termed its red coloring principle, is a compound of several principles.

Meier's (*Archiv. der Pharm.* lv. and lvi.) and Bolley's (*Chem. Gaz.* v. 423) recent investigations show the presence, in the wood, of six different substances, which may be extracted in part by water and in part by alcohol.

1. *Santalic acid*. Crystallizes in microscopic prisms of a beautiful red color, and forming with alcohol solutions which are red when concentrated, and yellow if dilute. Is insoluble in water, but soluble in ether, imparting a yellow shade. The ethereal solution does not redden litmus. Melts at 219°, and decomposes beyond that temperature. Cold, concentrated sulphuric acid dissolves it with a dark-red color, but water separates it unaltered.

Nearly all its salts are dark violet, and those of the alkalies and alkaline earths are soluble in water.

2. *Santalic oxide*. A brown, amorphous, viscous mass, unalterable in the air, tasteless, inodorous, and imparting a brown color to its alcoholic solution. Is insoluble in water, and

but sparingly soluble in ether. Is neutral to test paper. The acids change the brown color of its solution to a reddish yellow.

3. *Santalide*. A dark red, tasteless, inodorous mass, insoluble in water, but soluble, with a red color, in alcohol and ether. The acids do not change its color, but the alkalis render it brown.

4. *Santaloide*. A yellow mass, insoluble in ether, but soluble in water and in alcohol, leaving a brown deposit. Alkalis brown the color.

5. *Santaloidide*. A dark brown, resinous mass, unalterable by exposure, soluble in boiling alcohol of .863, and insoluble in ether and water. Caustic alkalis change the brown color of its solutions to red.

6. *Santalidide*. An amorphous, brown mass, insoluble in ether and absolute alcohol, but soluble in water and hot alcohol of .912. The brown color of its solutions is darkened by alkalis, and rendered yellow by acids.

SANDIVER. Syn. Glass gall. The saline scum which rises to the surface of molten GLASS during the process of manufacture.

SANDSTONE. *Geol.* Sand formed by the disintegration of rocky masses, is washed down by streams, and forms large deposits in the beds of rivers and in the ocean. When such beds are raised up above water-level, the oxide of iron they contain is carried through it by springs, deposits it among the sand, and cements the whole together into yellow or red sandstones. If calcareous matter be deposited, it will form a calcareous sandstone. And in like manner siliceous matter deposited from solution, will produce a siliceous sandstone. Siliceous sandstones are harder and tougher than the others. Where a sandy deposit contains clay intermixed, an argillaceous sandstone will result; and spangles of mica produce a micaceous sandstone.

SANGUINARIN. *Chem. Pharm.* The medicinal principle of *Puccoon* or *Blood-root* (*Sanguinaria Canadensis*), first extracted by Dana. Formula $C_{37}H_{16}NO_8$ (Scheele). A tasteless, yellow powder, reddened by acids. Is insoluble in water, but soluble in alcohol and ether. Its salts are red, bitter, and soluble in water. Riegel found another principle accompanying it in the root, which forms colorless salts.

SANTALIN. See SANDERS.

SANTONIN. *Pharm. Chem.* Used in medicine as a vermifuge. It exists in several species of the genus *Artemisia*, and particularly in those producing the flower heads known in commerce by the name of *Semen contra*. Is doubtless a resin.

Prop. C_5H_3O (Heldt). Crystallizes from its alcoholic solution in nacreous prisms, which though neutral to test paper, combine with bases, and form salts. These crystals become yellow on exposure to light. Is insoluble in water, but soluble in alcohol, ether, and acids, from which latter water precipitates it unaltered.

Santonin-soda, $C_{30}H_{18}O_6$, $NaOH + 7HO$, and at 212° $C_{30}H_{18}O_6$, NaO , HO (Heldt). Forms acicular crystals, unalterable by air or light.

Santonin-baryta. $C_{30}H_{18}O_6$, $BaO + 2HO$ at 212° .

Chlorinated santonin. $C_{30}H_{16}O_6$, Cl_2 . (Liebig's Ann. lxi. p. 10.)

SAPONIN. A peculiar principle extracted from the *Saponaria officinalis* or *Soapwort*. It has also been found by Malapert in the *Gysophylla struthium*, *Agrostemma githago*, *Silene nutans* and *inflata*, *DIANTHUS*, *Caryophyllus*, *Cassius*, *Carthusianorum*, *Proliferus*; *LYCHNIS deoica*, *chaleadonica*, *flos cuculi*; in the *Cucubalus Behen*, and in the *Angallis arvensis*, and *cerulea*. Fremy also obtained it from horse-chestnuts. According to Martins and Bly, it is identical with the *quillagin* from the bark of the *Quillaia saponaria* of Chili.

Is a white, brittle, sternutative mass, of an acrid after-taste, forming a frothy solution with water. Is less soluble in strong alcohol, and insoluble in ether. By the action of acids and alkalis, it is changed into *saponic* or *esculic acid*, $C_{26}H_{23}O_{12}$, a white powder, soluble in alcohol, and sparingly in water.

SAPONITE. *Min.* Soapstone, Pionite, Seifenstein. Massive, whitish, greasy, very soft. It yields water in a tube, fuses to a blebby glass, and is wholly decomposed by sulphuric acid. Form. $2(3MgO, 2SiO_3) + Al_2O_3, SiO_2 + 6HO$. From Lizard Point, Cornwall, and Svärdsjö in Dalarne, Sweden. See also STEATITE.

SAPPAR. See KYANITE.

SAPPHIRE. See CORUNDUM.

SAPPHIRINE. *Min.* In small grains. $H. = 7 - 8$. $G. = 3.428$. Pale blue or green; vitreous; translucent. Infusible alone or with borax. Form. $Al_2O_3, SiO_2 + 3(MgO, Al_2O_3)$; the last member is spinell. From Fiskendes, Greenland.

SARCOCOLLIN. The purer portion of *Sarcocolla*, a peculiar vegetable product, which exudes spontaneously from the *Penca sarcocolla* and *P. mucronata*, and other species of *Penca*.

SARCOLITE. See CHABAZITE.

SARCOSIN. See KREATIN.

SARD, SARDONYX. See QUARTZ.

SARSAPARILLA. *Pharm.* The root of the *Smilax sarsaparilla* and other species of *Smilax*. Marquart (*Chem. Gaz.* i. 548) has given a table of the comparative examination of the several commercial varieties.

The general constituents are—volatile oil, bitter resin, salseparin, oily and extractive matters, starch, albumen, and salts.

Salseparin. Syn. Smilacin, Parillin, Sarsaparillin, Pariglin, Parillinic acid. Formula $C_{15}H_{13}O_5$. Is neutral and crystallizes; soluble in hot water, in alcohol and ether, imparting a bitter, nauseous taste. This is supposed to be the active principle of the root.

SASSAFRAS. *Pharm. Chem.* The root of the *Laurus sassafras*. Reinsch's analysis of the bark gave:—

Water	90
<i>Ethereal Extract.</i>	
Heavy essential oil	}
Light " "	
Matter analogous to camphor	
Fatty matter	8
Balsamic resin and wax	50
<i>Extracted by Strong Alcohol.</i>	
Sassafride	92
Tannin	58
<i>Extracted by Weak Alcohol.</i>	
Sassafride, tannin, and gum	68

Extracted by Cold Water.

Soluble albumen	6
Gum, red coloring matter, and salts	30

Extracted by Boiling Water.

Fecula, brownish red coloring matter, tannin, and salts	54
Fecula, tannin, &c., dissolved by a solution of caustic potassa	289
Vegetable fibre	247

1000

Sassafride. Crystallizes from its boiling, alcoholic solution in bright brown, crystalline grains. Is slightly soluble in ether and cold water, and acts feebly, as an acid, similar to the tannin.

Volatile oil. The commercial oil, obtained by distillation, is slightly yellow, of a strong odor, and acid taste. Spec. grav. 1.09 at 50°. Boils at 443°. Its steareopten, which crystallizes out at a very low temperature, is fusible by the heat of the hand.

SASSOLIN. *Min.* Boracic acid. In small tables and stalactites. $G. = 1.48$. Whitish, pearly, greasy; taste feebly acidulous, saline, and bitter from impurities. It fuses readily, gives off water, and tinges flame green. It occurs in the Lipari Isles and in India, and is contained in the steam springs of Tuscany. See BORON.

SATIN SPAR. See CALCAREOUS SPAR.

SATURATION. *Chem.* This term is applied to two very different phenomena, namely, to the solution of a body in a liquid medium, and to the neutralization of a base by an acid, or of an acid by a base. A liquid is saturated with a salt or other solid, with another liquid or a gas, when it ceases to dissolve any more of that body. See SALTS.

Acids have the same capacity of saturation for all bases; that is, a certain quantity of an acid will exactly neutralize (or unite with a base to form a neutral salt) so much of any and every base as contains a definite, and the same quantity of oxygen. It is common to express how much oxygen is contained in the base neutralized by 100 pts. of the acid. Thus 100 pts. sulphuric acid will neutralize a quantity of potassa containing 19.96 pts. of oxygen, and so much of any other base as contains the same amount of oxygen; 100 pts. nitric acid neutralize as much base as contains 14.76 pts. oxygen. 19.96 is the saturating capacity of sulphuric, and 14.76 that of nitric acid. From the saturating capacity of an acid, it is easy to calculate how much it will take up of any base whose content of oxygen is known, and such a calculation is more accurate than a direct analysis, because the capacity of the acid has been determined by such means as lead to the most accurate result. On the other hand, when this capacity of an acid is known, we can determine from the quantity of a base which it neutralizes, the amount of oxygen in that base. It is by this means that the oxygen of those bases has been determined, which could not be directly analyzed.

SAUCY BARK. *Syn. Gidu.* This poisonous bark, much used on the coast of Africa for the purposes of witchcraft and of revenge, has recently been examined by C. A. Santos (*Am.*

Journ. Pharm. 1849), and found to contain tannin, gum, resin, resinous extract, chlorophyll wax, earthy and alkaline salts, and a crystallizable matter supposed to be the active principle, but not thoroughly examined, because of the limited quantity of material.

SAUSSURITE. *Min.* Magerer Nephrit, Lemanite. Crystalline. $H. = 5.5 - 6$. $G. = 3.256 - 3.34$. White, with greenish tint; pearly; very tough, with uneven, splintery fracture. It fuses on coal with difficulty on the edges to a greenish gray glass; is not attacked by acids. Form. $3 RO, SiO_3 + 2 (Al_2O_3, SiO_3)$, in which $RO = CaO, MgO, FeO, NaO$. With hornblende and augite it constitutes the rocks gabbro and euphotide.

SAVIN. The tops of the *Juniperus sabina*. An imperfect analyses by Needles gave, as the constituents of the leaves,—volatile oil, gum, tannin, resin, chlorophyll, fixed oil, bitter extractive, lime, and potassa salts. The essence resembles JUNIPER OIL, and has the same composition.

According to Winckler, savin oil yields, on distillation, mixed with sulphuric over lime, a new oil, identical with the *Oleum thymi æther.* (*Buch. Rep.* xlii. 331.)

SAXON BLUE. Solution of INDIGO in sulphuric acid.

SCAMMONY. *Pharm. Chem.* The gum-resinous exudation of the root of the *Convolvulus scammonia*. The genuine article yields to alcohol 60 to 80 pr. ct. of resin. It contains, besides gum, extractive, lignin, albumen, wax, starch, silica, salts, and foreign matters. It is entirely soluble in boiling dilute alcohol, partially in ether, and sparingly in water.

SCAPOLITE. *Min.* Meionite, Dipyre, Paranthine, Wernerite, Nuttalite. *Ger.* Tetra-klasit, Schmelzstein, Spreustein. Cryst. Quadratic; prismatic; also columnar, massive. $H. = 5 - 5.5$. $G. = 2.6 - 2.75$. White, gray, blue, green, red, usually light; lustre vitreous; transparent, subtranslucent; brittle, with sub-conchoidal fracture. They all fuse with intumescence to a clear glass, except wernerite from Pargas, which is semifusible; dissolve in both fluxes, leaving silica in mic. salt; fuse difficultly with soda to a clear glass, except wernerite and dipyre, which fuse more readily. In fine powder they are decomposed by muriatic acid.

It is impossible to give a formula for this mineral, one being $3 CaO, SiO_3 + 3 (Al_2O_3, SiO_3)$; another, meionite from Vesuvius, $3 CaO, SiO_3 + 2 (Al_2O_3, SiO_3)$; ekebergite, $3 CaO, 2 SiO_3 + 2 (Al_2O_3, SiO_3)$; wernerite from Petteby, $3 CaO, 2 SiO_3 + 4 (Al_2O_3, SiO_3)$. In both the last CaO is replaced in part by NaO . C. T. Jackson found 1.58 pr. ct. lithia and 2 pr. ct. oxides of cerium and lanthanum in the pink scapolite, from Bolton, Massachusetts; but C. Hartshorne found neither of these constituents in that mineral, from the same locality. The localities of scapolite are numerous.

SCARBROITE. *Min.* Is probably a mixture of hydrate and silicate of alumina, from the coast of Scarborough.

SCHEELITE. *Min.* Tungstein, Tungstate of lime. Cryst. Quadratic, consisting of 8-hedra and dioctahedra; also granular. $H. =$

SCHEERERITE.

4—4.5. G. = 6.076. White, sometimes yellow; vitreous; subtransparent, translucent; brittle, with uneven fracture. Fuses on coal to a translucent glass; dissolves in borax to a clear glass, but if saturated, becomes milky and crystalline on cooling; in mic. salt it dissolves in the outer flame to a clear glass, in the inner to a glass which is greenish while hot, but blue when cold; an addition of tin to the latter gives a darker color; it forms a swollen, half-fused slag with soda. It is readily decomposed by muriatic and by nitric acid. It is essentially tungstate of lime, CaO, WO_3 . It occurs with tin and wolfram at several places in Europe, in Chili, and in the U. S. at Monroe and Huntington, Connecticut.

SCHEERERITE. *Min.* In crystalline grains or laminae. Whitish, pearly, tasteless, inodorous, not unctuous. Fuses at 44° to an oily liquid, and volatilizes at 198° ; soluble in oil of vitriol with a red color; soluble in alcohol, ether, and the oils. Formula CH_2 .

Königl. A similar substance, fuses at 237° , and has the form. C_2H . See also FICHELITE, HARTIN, HARTITE, HATCHETIN, IXOLYTE, IDRIALIN, OZOKERITE, TURF.

SCHILLER SPAR. *Min.* Karstin; Schillerstein. Cryst. Triclinic, with one perfect cleavage. H. — 3.5 — 4. G. = 2.5 — 2.65. Dark olive-green; with copper-brown on cleavage plane; lustre metallic, pearly on same plane; subtranslucent; sectile, with uneven fracture and grayish streak. Yields ammoniacal water in a tube; becomes brown and magnetic when heated in the pincette; dissolves with difficulty in the fluxes, showing iron, chrome, and silica; fuses with soda to a brownish slag. Is more or less decomposed by sulphuric and by muriatic acid. If the chromic oxide be calculated as chromic iron ore, the formula becomes $3(\text{MgO}, \text{SiO}_3) + 2(\text{MgO}, 2\text{HO})$, a part of MgO being replaced by FeO , MnO , CaO . It occurs in or with serpentine.

SCHLIPPE'S SALT. *Syn.* Sulphantimonium of sodium. Van Den Corput prepares this salt by conveying into a red-hot Hessian crucible an intimate mixture of the following substances, reduced to a fine powder:—

Effloresced sulphate of soda.....	8 pts.
Sulphuret of antimony.....	6 “
Vegetable charcoal.....	3 “

The crucible is covered with a tile; when the fluid mass ceases to froth, and the sulphate is considered sufficiently reduced, the contents of the crucible are boiled in a porcelain dish with 1 pt. of sulphur and a suitable quantity of distilled water. The filtered liquid is set aside to crystallize, and in the course of a short time furnishes colorless or slightly yellowish tetrahedra, of a biting saline taste, with a hepatic, metallic after-taste. This salt is insoluble in alcohol, but soluble in 3 pts. of cold water. Its elementary composition is represented by the formula $3\text{NaS} + \text{SbS}_5 + 18\text{HO}$. (*Repert. der Pharm.*, March, 1848, and *Chem. Gaz.* vi. 268.)

SCHORL. See TOURMALIN.

SCHORLITE. See TOPAZ.

SCHRÖTTERITE. See Opaline-ALLOPHANE.

SCILLITIN. See SQUILLS.

SCOLEZITE. See MESOTYPE.

SELENIDE OF LEAD AND COPPER.

SCOLEZITE ANHYDROUS. See LABRADORITE.

SCORIA, SCORILITE. See OBSIDIAN.

SCORODITE. *Min.* Cryst. Right rhombic, with the main 8-hedron and vert. prisms. H. = 3.5—4. G. = 3.11—3.3. Pale green or brown, rarely bluish; translucent; vitreous, subadamantine; uneven fracture. It yields water in a tube, and becomes yellowish; on coal it gives off arsenical odor, and fuses to a magnetic slag; soluble in muriatic acid. It occurs at Vaulry, Dpt. Haute-Vienne; Schwarzenberg, Saxony; Carinthia; Cornwall, Brazil; Edenville, N. York.

SCORZA. See EPIDOTE.

SCOULERITE. See THOMSONITE.

SEA FOAM. See MEERSCHAUM.

SEA SALT. Chloride of SODIUM.

SEBACIC ACID. See OLEIN.

SECALIN. See ERGOT.

SEDATIVE SALT. The name given by the older chemists to Boracic acid.

SEIDLITZ POWDERS. *Pharm.* Used in medicine as a gentle aperient, and consisting of two powders (one containing Rochelle salts, Zij , and bi-carb. soda, ℥ij , in intimate mixture, and the other, tartaric acid grs. xxxv.), which when dissolved separately in water and mixed together, produce an agreeable effervescing draught.

SEIGNETTE'S SALT. *Syn.* Rochelle salt. The tartrate of soda and potassa. Schaffgotsch's recent formula is $\text{KaO}, \bar{\text{T}} + \text{NaO}, \bar{\text{T}} + 8\text{HO}$.

SELENALDIN. *Chem.* An artificial organic base, obtained by passing hydroselenic acid through an aqueous solution of ammoniated aldehyde of ammonia. Forms large crystals insoluble in water, but soluble in alcohol and ether. Its salts, with the acids, are crystalline and well defined. (*Wöhler and Liebig.*)

SELENIDE OF COPPER. *Min.* Massive; silver-white; metallic, with shining streak. It fuses to a gray, submalleable globule, evolving the odor of selenium; in an open tube it yields selenium, selenic acid, and copper remains. Formula Cu_2Se . From Skivevum, Sweden.

SELENIDE OF LEAD. *Syn.* Clausthalite. Granular. H. = 2—2.5. G. = 7.187. Bluish, lead-gray; metallic; sectile with granular, shining fracture, and dark gray streak. On coal it fumes, giving the odor of selenium, coating the coal red, yellow, and white, and coloring the flame blue; it does not fuse, but gradually sublimes, leaving a slag which tests of iron, copper, and sometimes cobalt; in an open tube it gives a red and gray sublimate of selenium. Decomposed by nitric acid in the cold, fully dissolved by heat. Form. PbSe . Tilkerode, and near Clausthal, on the Harz.

Selenide of lead and cobalt, from Tilkerode, is probably the same mineral, with several pr. ct. cobalt-selenide mechanically mixed.

SELENIDE OF LEAD AND COPPER. *Min.* Selenbleikupfer, Selenkupferblei. Granular. H. = 2—2.5. G. = 5.6—7. Lead-gray; metallic, with shining streak and grayish black powder. Fusible, and otherwise behaving like selenide of lead. Form. $\text{PbSe} + \text{CuSe}$, the PbSe being either as 1, 2, or 4, to 1 of CuSe .

SELENIDE OF MERCURY.

According to Frankenheim, Cu_2Se may be assumed as well as CuSe , and that the former is isomorphous with PbSe , which would give the simple form. PbSe , noting that a portion of Pb is replaced by Cu_2 . They occur at Tilkerode and Glasbach, near Hildburghausen, Hartz.

Zinken has found mercury in some of the above.

SELENIDE OF MERCURY. *Min.* Selenquicksilberblei. Cryst. Regular, cubic. $H. = 7.3$. Lead-gray to bluish or iron-black. In a closed tube it yields a gray sublimate of selenide of mercury, or by adding soda, metallic mercury; in an open tube, a fluid sublimate of selenite of mercury; on coal it gives the odor of selenium. It appears to be a mixture of PbSe with HgSe . From Tilkerode, Hartz.

SELENIDE OF SILVER. *Min.* Cryst. Regular, cubic. $H. = 2.5$. $G. = 8.0$. Color and streak iron-black; metallic. In a closed tube it fuses, forming but little sublimate; on coal it fuses quietly in the outer flame, with intumescence in the inner flame; reduced with soda and borax, it gives a globule of silver; readily soluble in fuming nitric acid. Form. AgSe , with a few pr. ct. of PbSe . From Tilkerode, Hartz.

SELENITE. See GYPSUM.

SELENITE OF LEAD. *Min.* Fibrous; sulphur-yellow; resinous; brittle, with white streak. Fuses in a tube by ignition to a dark drop, evolving selenium, and at a higher heat subliming selenious acid; fuses on coal, yields a globule of lead and a coating of selenium; the fluxes show copper, soluble in nitric acid. From the Friedrichsglück mine, near Hildburghausen.

SELENIUM. *Chem. Ger.* Selen. An element allied to sulphur, and occurring in very limited quantity with some native sulphur on the Lipari Isles, and in various native sulphurets; as in many galenas, in copper and iron pyrites, and in a few other ores. C. Fisher found it in the telluric bismuth of Virginia.

Prep. A reddish deposit in the manufacture of oil of vitriol from iron pyrites consists of selenium, sulphur, arsenic, tin, copper, mercury, lead, zinc, and iron. It is dried, mixed to a paste with aqua regia, gently warmed until the horse-radish odor is perceived, more acid then added, and when, after a couple of days, the color of the sulphur is greenish yellow, water is added, and the lead thrown down by sulphuric acid. Sulphuretted hydrogen is then passed through to precipitate sulphurets of selenium, arsenic, mercury, copper, and tin. The filtered and washed precipitate is treated with aqua regia, the filtered solution evaporated to expel most of the free acid, treated with potassa-lye in small portions, which precipitates copper, tin, and mercury, and the filtered solution evaporated and ignited in platinum to expel the last trace of mercury. The residue is rapidly powdered in a warm mortar, mixed with an equal weight of salammoniack, and heated to sublimation in a glass retort. Selenium sublimes with salammoniack and a small amount passes over into the receiver. The sublimate is washed with water, the selenium collected, washed on the filter and resublimed in a retort.

SELENIUM.

It may also be obtained by dissolving the deposit in potassa, and exposing the clear solution for a time to the air, by which hyposulphite of potassa is formed and selenium precipitates. By passing dry chlorine gas over the dry deposit in a porcelain tube, gradually heated, chlorides of selenium and sulphur pass over, which are caught in water, and the filtered liquid, treated with sulphite of potassa, deposits selenium. By subliming the dry deposit with 8 times as much binocide of manganese, selenium and selenious acid sublime, while sulphurous acid passes over. The latter caught in water deposits a little selenium, and the former is distilled again with manganese or treated with potassa and a sulphite as before. Selenium is obtained from galenas by washing the powdered ore with dilute acid to remove some lime and iron, igniting for an hour the dried residue with 8 times its weight of black flux, covered with coarse charcoal powder, grinding the cooled mass to powder in a warm mortar, throwing it on a filter, and washing with boiled water, as long as the seleniuret of potassium passes through colored; the filter should be kept filled with water to avoid oxidation. The colored solution exposed to the air in shallow vessels deposits selenium and incrusts the surface of the liquid; the crust is broken until it ceases to form.

Prop. It crystallizes in 4-sided prisms, of spec. grav. 4.3—4.32; after rapidly cooling the fused selenium it has a metallic lustre and brilliant fracture, is black or brownish black, transmits red light in thin layers, is brittle, easily powdered, with a dark red streak; by precipitation by sulphurous acid, it is red or yellow, according to the dilution. It softens by heat and may be drawn out in threads, nearly fuses at 212° and at a little higher heat is perfectly liquid, boils below a red heat, giving a darker yellow gas than chlorine; by heating in the air it burns to selenious acid with a little oxide. It is an imperfect conductor of heat and electricity. Sym. Se. Eq. = 39.72, (or $495.285 \text{ O.} = 100$, Berz.)

Oxygen. 1. *Oxide of Selenium* forms, when selenium is burned in oxygen or air, with selenious acid, which is removed by water. It is colorless, of a penetrating odor; most resembling horse-radish, and so powerful that $\frac{1}{30}$ grain would fill a room with the odor; it imparts the same odor to water. Probable form. SeO .

2. *Selenious acid*, SeO_2 . Obtained by dissolving selenium in warmed nitric or nitromuriatic acid, distilling off the acids and then subliming selenious acid in a retort. It sublimes in 4-sided needles, or a dense white layer, volatile nearly at the boiling point of oil of vitriol, forming a yellowish gas, has a strong acid and burning taste, is readily soluble in cold, and in almost every proportion in hot water, very soluble in alcohol. A hydrate crystallizes out of a hot solution on cooling. It is decomposed by heating with ammonia; in the cold and in solution by sulphurous acid or sulphites by sulphohydrogen and by zinc and iron.

Salts. Selenious acid has not as strong an affinity for bases as the sulphuric. They are neutral, bi- and quadrisalts, the last only with alkalis, and a few basic salts. The neutral

alkaline are soluble and have an alkaline reaction, the rest insoluble; the acid salts are very soluble and have an acid reaction. Most are decomposed by heat, losing all or part of the acid; and more readily decomposed by heating with charcoal, selenium being either evolved, as with the earthy salts, or forming a seleniuret, as with the alkalies and some metallic oxides; their solution is also decomposed like that of the acid itself. *Analysis.* The presence of selenium is known by heating with soda or microcosmic salt on charcoal by the blow-pipe, when the horse-radish odor is evolved. It is precipitated in analysis by acidulating the solution with muriatic acid, adding an alkaline sulphite and heating the liquid to make the selenium collect; if now the addition of alkaline sulphite produces no red color, it is all precipitated. It is collected on a weighed filter, very carefully dried and weighed. Selenic acid is converted into selenious acid by boiling with muriatic acid; or the substance may be fused with nitrate of potassa, dissolved in water and determined as selenic acid by baryta, like sulphuric acid. Selenious and selenic acids are separated from those metals, not precipitable by sulphohydrogen, by that agent, and from most of those that are, by sulphhydrate of ammonium, in which sulphurets of selenium are soluble. Selenium is separated from tellurium and arsenic by igniting with alkaline nitrate, dissolving in water, acidulating with nitric acid and precipitating with nitrate of baryta in which the seleniate is insoluble. The selenious may generally be determined by its decomposition with sulphurous acid or sulphites.

3. *Selenic acid*, SeO_3 . It is obtained in combination by fusing selenium or its compounds with alkaline nitrates, and the liquid acid by action of chlorine or hypochlorous acid on selenium or selenious acid in water. It is a clear liquid, which may be evaporated to a spec. grav. 2.61 at a temperature of 536° , when it consists of SeO_3 , with a little more than 1 HO ; heated more highly, it separates into selenious acid and oxygen. It heats like oil of vitriol by mixture with water, dissolves iron and zinc with disengagement of hydrogen; is not decomposed by sulphurous acid nor sulphohydrogen.

Salts. The acid has almost as strong an affinity for bases as the sulphuric acid. Its salts are isomorphic with sulphates, chromates, and manganates. They generally bear ignition without decomposition, but with charcoal they evolve the characteristic odor of the oxide of selenium. By boiling with chlorohydric acid, the selenic is reduced to selenious acid. The neutral salts are soluble in water, but those of baryta, strontia, lime, and lead, are insoluble, or with difficulty in water or nitric acid water.

Bisulphuret of Selenium, SeS_2 , is formed by precipitating selenious acid by sulphuretted hydrogen; appearing first as yellow, but by heating the liquid, collecting as a denser, bright red mass. It fuses a little above 212° ; by a little caustic potassa, a portion of sulphur is extracted; by more potassa, all the sulphur and a little selenium, leaving the rest of the latter pure; sulphuretted alkali also extracts sulphur and selenium, and in excess dissolves it.

Halogens. Selenium unites readily with phos-

phorus, iodine, and bromine in many or nearly all proportions, and it appears to form a compound with fluorine, but its combinations with chlorine are more definite. When chlorine is passed over selenium, it forms a brown liquid, Se_2Cl , volatile and heavier than water, which decomposes it into muriatic and selenious acids and selenium. If the passage of chlorine be continued, it forms a white, solid mass, bichloride of selenium, SeCl_2 , which volatilizes as a yellow vapor, and decomposes with water into muriatic and selenious acids; $\text{SeCl}_2 + 2\text{HO} = \text{SeO}_2 + 2\text{HCl}$.

Biseleniuret of Carbon appears to be formed by distilling yellow prussiate of potash with an excess of selenium; for the colorless liquid which distils over has the odor of bisulphuret of carbon. The residue contains a body corresponding to sulphocyanogen or rhodan, and is called by Berzelius, cyanselelan; its formula is $\text{C}_2\text{N}, \text{Se}_2$. It has not yet been minutely studied.

Seleniuretted Hydrogen. Syn. Selenhydric acid, Selenhydrogen. HSe . It is obtained by acting on seleniuret of potassium or iron by muriatic acid and water. The gas is caught over mercury. It is a colorless gas, with precisely the same odor as sulphohydrogen at first, but subsequently pungent and painful, and very injurious. It is largely absorbed by water, and precipitates most metallic salts, as brown or black seleniurets, those of cerium, manganese, and zinc, flesh-red.

Selenides are formed direct by heating metals and selenium, by precipitating metallic solutions by selenhydrogen or by seleniuretted alkali; the alkaline seleniurets, with excess of selenhydrogen, form selenhydrates, and these precipitate the same salts of the earthy bodies, and of zinc and manganese.

Selenite of Potassa. The neutral and bi-salts crystallize by evaporation, and are very soluble in water; the former is insoluble, the latter scarcely soluble in alcohol; the quadriselenite is deliquescent, uncrystallizable. The three salts of ammonia and of soda are similar, but the quadriselenite of soda is crystallizable. The neutral salts of baryta and strontia are white, insoluble in water, soluble in acids; the acid salts are slightly soluble; the neutral salts of lime and magnesia are slightly soluble, the acid salt of magnesia deliquescent. Insoluble in water are the neutral salts of glucina, yttria, zirconia, alumina, oxides of cerium, zinc, manganese, peroxide of iron, cobalt, nickel, tin, lead, copper, and both oxides of mercury; bi-salts of alumina, glucina, peroxide of cerium, zinc, cobalt, nickel, red oxide of mercury, are soluble. Protoselenite of iron is insoluble, white, turning to yellow in the air; acid perselenite is insoluble in water, soluble in muriatic acid; the neutral salt of cobalt is red, of nickel, green, of copper, greenish blue.

Seleniate of Potassa, made by fusing saltpeter and selenious acid, and crystallizing, has the same form. as sulphate of potassa, and deflagrates on ignited coals. *S. of Soda* crystallizes without water, like dry sulphate of soda, and shows the same peculiar solubility in water, being most soluble at 91.4° . *S. of Baryta* is as insoluble as the sulphate. *S. of Magnesia* has both the form, and solubility of Epsom salt;

SELENPALADITE.

the selenites of *copper* and *silver* have the same form. as the sulphates.

SELENPALADITE. Is native PALLADIUM.

SELENSULPHURET OF MERCURY. *Min.*

Granular. $H. = 2.5$. Steel to blackish lead-gray; metallic, with shining streak. In a closed tube it wholly sublimates black; with soda yields mercury, and on coal gives both the odor of selenium and sulphur. Formula, $HgSe + 4 HgS$, or simply HgS , in which part of the sulphur is replaced by selenium. From San Onofre, Mexico.

SEMEN. The glutinous seminal fluid secreted in the testicles contains, according to Vauquelin's analysis,—

Peculiar extractive matter.....	6
Phosphate of lime.....	3
Soda.....	1
Water.....	90

John found a substance resembling mucus, a peculiar form of albumen, a matter slightly soluble in ether, soda and chloride of sodium, phosphate of lime, sulphur, and a volatile odorous principle. (*Simon's Chemistry of Man.*)

SEMIOPAL. See OPAL.

SENEGIN. See POLYGALIA.

SENNA. See CATHARTIN.

SEPTARIA. *Geol.* Nodules contained in clay or sand.

SERICIC ACID. See MYRISTICA OFFICINALIS.

SEROLIN. See BLOOD.

SERPENTINE. *Min.* Many hydrous silicates of magnesia are allied to serpentine in their external characters and composition, and will probably prove to be slight modifications of a single mineral composition, which we may call serpentine. See varieties below. The crystalline form is uncertain, as it is so often a pseudomorph. $H. = 3-4$. Grav. about 2.5. Color of various shades of green, from very light apple- and yellowish green to almost black; lustre greasy, almost dull; translucent, opaque; sectile with conchoidal and splintery fracture, and white streak; usually very unctuous to the touch. It yields water in a tube, and blackens; burns white on coal, and fuses on thin edges to an enamel; yields a greenish glass with borax, and leaves silica in mic. salt; fuses with a little soda, but with more only swells; gives a pale red with cobalt; decomposed by muriatic, better by sulphuric acid. A large proportion of analyses lead to the formula $[2 (3 MgO, 2 SiO_3) + 3 HO] + 3 (MgO, HO)$. The localities of serpentine are numerous, among primary rocks.

SERUM. The more aqueous portion of the animal fluids, exhaled by serous membranes.

SEVERITE. See HALLOYSITE.

SEYBERTITE. See CLINTONITE.

SHALE. *Geol.* A name given to crumbling slates.

SHELLAC. See LAC.

SCHIST. *Geol.* Schist. The same as Shale.

SIDERITE. See CUBE ORE.

SIDEROCHALCITE. See APHANESITE.

SIDEROCHISOLITE. See CHAMOISITE.

SIENTITE. See GEOLOGY.

SIENNA EARTH. *Tech.* A dark brown earth, from Italy, employed as a pigment after calcination. It is a hydrated oxide of iron,

SILICIUM.

with silica and a notable quantity of arsenic (arsenious ?) acid, $8\frac{1}{2}$ pr. ct. Umber likewise contains traces of arsenic. (*Maus in Chem. Gaz.* i. 498.)

SILEX. A common name for QUARTZ.

SILICA. See SILICIUM.

SILICEOUS BISMUTH. See BISMUTH BLENDE.

SILICEOUS MALACHITE. See ACHIRITE, CHRYSOCOLLA, DIOPHASE.

SILICEOUS MANGANESE. *Min.* There appear to be three principal varieties, MnO, SiO_3 , and $MnO, 2 SiO_3$, and $MnO, 3 SiO_3 + 2 HO$. See MANGANESE SPAR.

SILICEOUS SINTER. *Geol.* A name properly applied to the siliceous deposits of certain hot springs, and composed of silica, oxides of iron and manganese, alumina, lime, water, &c.

SILICEOUS ZINC. *Min.* Electric calamine, Galmei (in part), Zinkglas. Cryst. Right rhombic, with a perfect cleavage parallel to a rhombic prism; also imitative granular and massive. $H. = 4.5-5$. $G. = 3.435-3.871$. White, various colored; vitreous; transparent, translucent; brittle with uneven fracture and white streak; polar-electric by heat or friction. It yields water in a closed tube; on coal scarcely fuses on the edges, and gives a zinc coating; with cobalt solution it becomes green, and on the fused edges blue; decomposed by nitric acid and by potassa solution. Form. $2 (3 ZnO, SiO_3) + 3 HO$, or $3 ZnO, SiO_3 + 2 HO$. It occurs with calamine. See CALAMINE and WILLIAMITE.

SILICITE. See LABRADORITE.

SILICIUM. *Chem. Syn.* Silicon. *Ger.* Kiesel. The metallic basis of silica or silex, and equally abundant with oxygen as a constituent of the solid surface of the globe, and also constituting a large portion of aerolites, from the regions of space. The basis of silex was first obtained pure in 1823, by Berzelius.

1. *Silicium. Prep.* Well-dried silicofluoride of potassium, 10 pts., are mixed with 8 or 9 pts. potassium in an iron or glass tube, and the potassium fused and stirred with the salt by an iron wire. It is then heated by a spirit-lamp, when it suddenly becomes ignited from the reduction of silica by the potassium, forming a brown mixture of fluoride and silicuret of potassium. It is thrown into cold water, when hydrogen is evolved, the potassium of the silicuret being oxidized by water, and the silicium separating. When the effervescence has ceased, the solution is poured off, fresh cold water added, and poured off, until it ceases to be alkaline, when boiling water is used to wash the silicium, as long as it extracts any thing.

Another method of preparing it is to put potassium into a bulb in the middle of a tube, moisten it with chloride of silicium, and attach a small retort with chloride of silicium to one end of the tube. The chloride is made to boil by heat, and the potassium heated at the same time, whereby air is expelled the tube. As soon as the potassium is dried, it inflames in the vapor of the chloride of silicium, which is now driven rapidly out of the retort, forming chloride of potassium and silicium, and is finally heated in the gas to ignition. After cooling, the excess of chloride of silicium is

expelled by a current of dry air passed over the warmed bulb, and the whole thrown into water, which dissolves out chloride of potassium and silicium.

Prop. A dark brown powder, soiling the fingers, infusible, but like borax and carbon, become more dense and darker in color. The first modification, α Si, is inflammable in the air by heat, about $\frac{1}{4}$ burning to silica, which coats the second modification, β Si. The former is not oxidized by sulphuric, nitric, or nitromuriatic acid, even boiling, but is readily soluble in warm potassa solution, and in cold fluohydric acid. The second modification, obtained by burning silicium in the air and removing silica by fluohydric acid, is dark chocolate-brown, heavier than oil of vitriol, incombustible either in the air or oxygen, or even when gently ignited with salt-peter. It is also insoluble, even in boiling fluohydric acid or potassa, but is readily soluble in nitro-fluohydric acid. Sym. Si. Equiv. 22.185 (277.312. O. = 100, Berz.).

2. *Silicic acid.* Syn. Silica, Silex, Kieselsäure. SiO_2 . Silica, in the various forms and appearances of quartz, constitutes a very large proportion of the solid crust of the globe, and is the principal constituent of the larger proportion of all simple minerals, forming a greater variety of salts than any other acid. It is easily prepared pure from powdered quartz, sand, feldspar, or other siliceous minerals, by fusing them with 4 times their weight of a mixture of carbonate of potassa and soda (or by either carbonate alone), dissolving when cold in dilute muriatic acid, filtering, and evaporating the solution to dryness by a gentle heat, digesting in muriatic acid, filtering, and washing with hot water.

Prop. It has two modifications, the one soluble in water and acids, the other insoluble:—Soluble, α SiO_2 , is that obtained in the above process for preparing silica, but purer by the oxidation of sulphuret of silicium by water. It is always formed by fusing silicates with alkali, but may also be formed by boiling fine silex with strong alkaline solutions. It is soluble in water and acids, and when the solutions are concentrated, it usually separates as a jelly (gelatinous silica), and when evaporated to dryness, passes into the insoluble modification. β Silica is a white, gritty powder, insoluble in water and acids, infusible in the highest heat of our furnaces, but fusible in a stream of oxygen driven through an alcohol flame. It fuses in this case to a clear glass, which may be drawn out into flexible threads. When the fused bead is dropped into water, it becomes so hard as to indent a steel pestle and mortar. It is volatile in the vapor of water, for a current of steam passed through a white-hot furnace condenses large quantities of silica at the top as a snow-white powder. It is the feeblest acid at common temperatures, but by a high heat can expel all volatile acids. For its many acid and basic salts, see SALTS. Gmelin and others have assumed that the formula of silicic acid should be SiO_2 , but Berzelius gives grounds for assuming it at SiO_3 , and this view has been confirmed by Kopp on totally different grounds.

3. *Sulphuret of Si*, SiS_2 , obtained by heating

silicium in vapor of sulphur, is white, earthy, decomposable by moist air and water, yielding sulphohydrogen and soluble silicic acid, without deposition of sulphur.

Chloride of Si, SiCl_3 , is made by mixing fine silica, charcoal, and oil to a stiff paste, charging it in a close crucible, pulverizing, putting it into a porcelain tube, and passing dry chlorine gas over it while it is ignited. A cooled receiver condenses the chloride with excess of chlorine, which is removed by shaking with mercury, and the latter may even contain a little potassium. It is purified by redistillation. It is a very volatile liquid, boiling at 122° with a very pungent, acid odor, fuming in the air, decomposed by water into muriatic and silicic acids.

4. *Bromide of Si*, SiBr_3 , similarly made and purified, is a colorless, fuming liquid, solidifying at from 5° to 10° , and boiling at about 300° .

5. *Fluoride of Si*, SiF_3 . It is prepared by mixing equal parts of finely-powdered fluor spar, and coarse sand or powdered glass, with 6 pts. oil of vitriol in a capacious vessel, and applying warmth when the action diminishes. The gas is caught in perfectly dry glass, over mercury. It is a colorless gas, with a strong, pungent odor, fuming in the air, decomposable by water, largely absorbed by absolute alcohol, condensing with ammonia to a peculiar compound, forming with metallic oxides, silica, and fluorides.

Silicofluohydric acid, Fluosilicic acid, $3\text{HF} + 2\text{SiF}_3$. Prepared by passing the fluoride into water; but the deposit of silica at the end of the tube being apt to close it, this end should be thrust under mercury, beneath the water; $3\text{SiF}_3 + 3\text{HO} = (3\text{HFl} + 2\text{SiFl}_3) + \text{SiO}_2$. When the liquid is full of silica, the whole is brought upon a filter, drained and pressed, but not washed, because the silica is soluble in water. The liquid acid has a pure acid taste, can be somewhat concentrated by evaporation, but if pushed too far, fluoride of silicium is evolved, and fluohydric acid remains; its most striking character is to form with neutral salts of potassa, soda and lithia, gelatinous and almost transparent precipitates, and with barytic salts, a white, crystalline precipitate. Crystallized boracic acid absorbs the gaseous acid, forming a white powder, $\text{SiF}_3 + \text{BO}_3, 3\text{HO}$, which is decomposed by water, and a portion dissolves as $\text{SiF}_3 + 3\text{BoF}_3$.

Silicofluoric acid forms silicofluorides of the metals in which, as in the acid, the 2SiF_3 seems to be the pairing, and their general formula is $3\text{MF} + 2\text{SiF}_3$. The salts of the alkalis, made by dropping silicofluohydric acid into the solutions of an alkaline salt, are nearly transparent when freshly precipitated, but dry to white powders, are almost insoluble in cold, (the sodium salt being most soluble,) more soluble in hot water; are fusible, but then decompose and lose fluoride of silicium. The salt of ammonium, made by subliming a mixture of a fixed alkaline silicofluoride, is white, soluble in water, crystallizable, and has the formula $\text{NHf} + 2\text{SiF}_3$.

The insolubility of the barium salt, and the solubility of that of strontium, offers a mean of separating these bodies in analysis. The calcium salt is slightly, and the magnesium salt

very soluble in water. Nearly all the salts of the earths and metals proper are soluble in water, except that of yttrium. By heat they lose fluoride of silicium, and a simple metallic fluoride remains. They are readily made by dissolving the fresh hydrated oxide or the carbonate in silicofluohydric acid, and evaporating to crystallize.

SILLIMANITE. *Min.* Cryst. Oblique rhombic, with a perfect cleavage; also fibrous. *H.* = 7—7.5. *G.* = 3.2—3.26. Brown; vitreous, splendid on cleavage; translucent; brittle, with white streak. Infusible, not attacked by acids. Form. Al_2O_3 , SiO_2 ; allied to kyanite and bucholzite, (identical with them, *B. Silliman, Jr.*) It occurs at Chester and Norwich, Conn., &c.

SILVER. *Chem.* *Ger.* Silber. *Fr.* Argent. *Lat.* Argentum. Silver, known from the earliest times, occurs frequently but not abundantly in the mineral kingdom. It is often found in the metallic state, and masses of many hundred pounds have been obtained, but it is more frequently mineralized with sulphur, antimony and arsenic in ruby-silver, vitreous-silver, gray-copper, galena, &c.

METALLURGIC TREATMENT OF SILVER ORES.

Rich ores are generally fused with lead, the poorer amalgamated, galenas are reduced to metallic lead, and copper ores treated with lead, or reduced to copper, which is smelted with lead. The argentiferous lead obtained is cupelled for silver.

1. *Amalgamation.* The Mexican process consists in making heaps of the stamped ore, mixing it with about 10 pr. ct. salt, by treading with mules, and then adding 1 to 3 pr. ct. *Magistral*, which is ground and roasted iron and copper pyrites. A little lime is added in summer, and half as much *magistral* in winter. This is troden for several days by mules, and mercury added, (about 6 or 8 times as much as the ore contains silver), which is also incorporated by treading until a test shows that the amalgamation is complete. Mercury is added again and again, and often some *magistral* and lime. The process requires from 2 to 4 weeks, and even longer. The ore is then transferred to cisterns with an upright shaft and arms, which is turned while water is let in, in order to make the amalgam settle and remove the ore. After cleaning the amalgam, it is pressed through canvas bags, the liquid mercury passing through the pasty amalgam remaining in the bags. The pasty amalgam by heat loses mercury, and a mass of porous silver remains.

Very poor ores are worked in this manner, but the loss of mercury is considerable. The *magistral* contains sulphates of iron and copper, and by contact with the salt form chlorides of iron and copper. The chloride of copper forms chloride of silver, which is reduced by mercury, chloride of mercury being formed, and the amalgam formed.

2. The Saxon method consists in mixing the sulphuretted ores so that the salt to be mixed with it will be decomposed by roasting. The ore, mixed with 10 pr. ct. salt, is then roasted in a reverberatory furnace with constant stirring, the burning sulphur assisting the heat. A part of the sulphur passes off as sulphurous acid, and part forms metallic sulphates; when

the former ceases to form, an increased heat is given, by which the sulphates decompose the salt, forming sulphate of soda. The roasted and cooled ore is sifted, the coarse being re-ground, salted and roasted, and the very fine is ground and submitted to amalgamation. The ore is put into horizontal revolving drums or barrels, water and scraps of iron added; to 10 cwt. ore, $2\frac{1}{2}$ cwt. water and $\frac{3}{4}$ — $\frac{7}{8}$ cwt. iron, which last is renewed as it dissolves. After being mixed by revolving, 5 cwt. mercury is added and the revolutions continued for 14 to 16 hours, the drums making 20 to 22 revolutions per minute. When the amalgamation is complete, the drums are filled with water, revolved slowly, 6 to 8 times per minute, by which the amalgam collects at the bottom. A small hole in the bung is then opened, and the amalgam flows into a cistern, in which the amalgam from many barrels is collected. The clean amalgam is pressed in bags, and the remaining solid distilled to obtain the silver. The residue in the barrels is stirred in vats, as in the Mexican process, to collect the remaining amalgam. By the roasting process metallic chlorides are formed, and these are reduced in the barrels by iron, so that the amalgam contains silver, copper, lead, &c.

3. For the treatment of copper, containing silver, see metallurgy of COPPER, 4, b, p. 478.

4. When lead and copper sulphurets occur together and contain silver, or where galena and gray copper are mixed; they are first smelted by the addition of iron, by which lead is obtained, rich in silver, and lead-stone, 1; the latter roasted and again smelted, gives also a rich lead, and lead-stone, 2; a third roasting and smelting yields but little lead, and lead, or rather copper-stone, 3, which contains 40 to 48 pr. ct. copper, and is worked for that metal.

Cupellation. Argentiferous lead may be worked for silver by cupellation, if it contains above 10 oz. silver to the ton, in Freiberg 14 oz.; but by Pattinson's process, still lower may be worked. The cupel is a reverberatory with a porous hearth (*Treibheerde*), of a round or oval form. The upper layer of the hearth consists of sifted and leached wood ash, mixed with lime, clay, marl, or bone-ash. It is basin-shaped, with a depression in the centre to receive the silver, and a gutter to run off litharge on one side. The metal being put on the hearth, it is fused by the flame playing over its surface, and the lead and other metals except silver oxidized, and with the fused litharge run off through the gutter. The first portions run off are dark colored from copper, iron, nickel, &c., and contain a little silver. When the litharge begins to run clear, (yellowish), the heat is diminished, and the blast admitted, which strikes the surface of the metal at an angle, and playing over it, oxidizes it to litharge. The latter flows continually through the gutter, which is cut deeper as the surface of the metal diminishes in height. Towards the close of the process, when the quantity of lead diminishes, the increasing proportion of silver renders the alloy less fusible, the fire is increased, until finally, a peculiar movement is observed on the surface of the metal, and it is then quiet and brilliant. The fire and blast are removed, and the silver cake refined by

fusion with some soft lead and recupelling on a hearth, better prepared. In the latter case, the action is similar to that of the cupel for assaying. See *CUPEL*. A movable hearth is employed in England, and called a *test*.

The quantities of silver annually produced in America, Europe and northern Asia, is over 1000 tons, or more than 2½ million lb. troy. It is probably about \$50,000,000 annually.

SILVER AND ITS NON-SALINE COMPOUNDS.

1. *Silver*. It was formerly obtained in a purer form by precipitating a solution of silver by metallic copper, and washing thoroughly with ammonia; but the more common methods consisted in precipitating chloride of silver by common salt, washing and reducing it by potash. The best method is to cover the washed chloride by water, throw granulated zinc into it, and then sulphuric or muriatic acid. A few drops of acid only are required, but more is used to promote a rapid decomposition, and still more used to dissolve the excess of zinc. The reduced metal is washed with acid water, then with hot water, and finally fused with borax and saltpeter.

Prop. When precipitated, it is a gray powder, which by friction shows a white metal; when fused, it is the whitest of all metals, receives a high polish, is harder than gold, highly malleable and ductile, forming leaves of $\frac{1}{1000}$ inch thick, and one grain forming a wire 400 ft. long; sp. grav. of the fused 10.428—10.474, of the hammered 10.50. It tarnishes in the air of cities, from sulphurous fumes, and in salt air from chloride, which darkens by light; it attracts oxygen in the melted state, which it parts with again on cooling, and hence the jagged appearance of a cooled bead, from its spiriting by the escape of oxygen. Sym. Ag. (Argentum) Equiv. 108 (1349.66 O = 100 Berz.)

2. *Oxide of Silver*. AgO, containing 93.103 pr. ct. metal. It is prepared by precipitating a solution of silver by a solution of potassa or baryta, washing and drying by a gentle heat. It is a brown powder, almost black if high dried, slightly soluble in water with metallic taste and alkaline reaction; easily reduced by light or heat, and by hydrogen at 212°.

Salts. Oxide of silver is a strong base, and its neutral salts have a neutral reaction; they are colorless, unless the acid be colored, have a metallic taste, and are poisonous. The nitrate, sulphate, and a few others are soluble, but most are either insoluble or slightly soluble in water. All the insolubles are soluble in nitric acid and in ammonia. The metal is thrown down from solutions by zinc, cadmium, lead, tin, iron, copper, mercury, bismuth, tellurium, antimony, arsenic, phosphorus, phosphorous and sulphurous acids, phosphohydrogen, copperas, tin-salt, and many organic bodies, especially by heat. Muriatic acid and muriates precipitate white chloride of silver, curdy in strong solution, opalescent in a dilution of 1 to 2—300,000 water; iodhydric and bromhydric acids and their salts precipitate a yellowish iodine or bromide in strong solutions, white or opalescent in the same dilution as the chloride; of these the chloride is very soluble in dilute ammonia, bromide in strong ammonia and iodine scarcely in the strongest.

It is thrown down as brownish black sulphuret by sulphohydrogen and alkaline sulphurets, in a dilution of 1 to 25,000. Potassa and soda precipitate brown oxide; ammonia produces a cloudiness which disappears by an excess; carbonated alkali, white carbonate soluble in carbonate of ammonia; arsenite and common phosphate of soda, yellow arseniate or phosphate soluble in free acid; pyro, and metaphosphated alkali white; chromate a dark red, arseniate a brownish red; cyanohydric and cyanides, sulphocyanide, yellow prussiate of potash and oxalic acid, white; red prussiate, reddish brown. In the blow-pipe flame, the compounds of silver yield a globule of the metal; with borax and mic. salt in the outer flame a milk-white or opalescent bead. A peroxide of silver is obtained on the positive pole of a galvanic battery discharged through a dilute solution of the metal, as crystals with a metallic lustre.

A solution of oxide of silver in ammonia gradually deposits suboxide. By passing hydrogen over oxalate, citrate, or mellate of silver, at 212°, they are reduced to salts of suboxide, and by solution in water and precipitation by potassa, a black suboxide falls down.

Ammonia-oxide of silver is obtained by precipitating nitrate of silver by lime, partly drying the precipitate on paper, pouring over it strong ammonia, and after 12 hours pouring off the liquid, and dividing the sediment on many pieces of paper to dry. It is a black powder, highly explosive by heat, electricity or touch. The solution also deposits black, crystalline particles, which are even more explosive than the preceding, such as by agitation of the liquid, or touching them in the liquid.

3. *Sulphuret of S.* AgS. Found native as vitreous silver. Made by fusing silver and sulphur together, or precipitating a solution of silver by sulphohydrogen or an alkaline sulphuret. It is black, fusible, sectile, with a dark lead gray shining streak, and somewhat malleable. Decomposed by calcination into sulphurous acid and silver, by strong nitric acid into sulphur and nitrate of silver.

4. *Carburet of S.* By ignition of silver with lampblack AgC is formed; by strong ignition of cyanide of silver, fused AgC is produced. By heating pyroracemate of silver for a long time in a water-bath and distilling, AgC₂ is formed.

5. *Phosphuret of S.* is formed by direct action at ignition, or igniting phosphate with charcoal. It is white, granular, sectile and brittle.

6. *Siliciuret of S.* is obtained by heating a mixture of silver powder, charcoal and silicic acid under an alkaline-glass flux.

7. *Alloys*. Arsenic, antimony, bismuth, tin, and zinc form brittle alloys with silver. Cobalt and nickel unite in small quantity with silver, rendering it brittle, and in like manner silver in small quantity unites with those metals. Manganese and silver form an alloy. Copper and silver unite in every proportion with copper, and the proportion is more or less indicated by the color of the alloy. From all these, the silver may be obtained by cupellation. Iron and silver fuse together, and cannot be separated by cupellation, but readily by solution

SILVER.

and precipitation by muriatic acid or a muriate, or by fusion with borax and saltpeter. See **CUPELLATION, ALLOY**. Silver alloys with the precious metals, and gives less malleable alloys, except with gold and iridium.

HALOID SALTS.

1. *Chloride of Silver*, AgCl , containing 75.33 pr. ct. silver. It is readily formed by adding muriatic acid, or a soluble muriate to a solution of silver in nitric acid, washing and drying apart from light. It is white, fusible at 500° to a clear, yellow liquid, and volatilizes unaltered at a very high temperature. It congeals to a transparent, colorless solid, so soft as to receive an impression from the nail. It blackens by exposure to air, is insoluble in water, readily soluble in ammonia, alkaline hyposulphites, less in muriatic acid and alkaline chlorides. It is decomposed by fusion with fixed caustic and carbonated alkali, by ignition with a carbohydrogen, as rosin, &c., and by the following metals under water, especially if acidulated, zinc, cadmium, bismuth, tin, lead, iron, copper, mercury, arsenic, antimony.

A subchloride, Ag_2Cl , is formed by exposure of the chloride to light, by decomposing it with chlorides of copper, mercury, and perchloride of iron, or by the action of muriatic acid on suboxide of silver. It is a brownish or black powder with metallic streak, which, when heated to the fusing point of chloride, separates into metal and chloride.

Chloride of silver forms double salts with alkaline chlorides, by boiling them together, when the compound salt separates in crystals on cooling. By dissolving chloride of silver in cyanide of potassium, and evaporating, a crystalline, double salt separates.

2. *Bromide of S.*, AgBr , formed like the chloride by a soluble bromide, is yellow, fuses to a red liquid, and congeals a yellow translucent soft mass; it otherwise resembles chloride, but is only slightly soluble in dilute ammonia; disseminated in water it is readily decomposed by chlorine, with more difficulty as a dry powder. It forms double salts with alkaline bromides.

3. *Iodide of S.* Formed by an iodide, like chloride, and also by heating the two elements together. It resembles chloride and bromide, is yellow, fuses to a red liquid, congeals to a dirty yellow, opaque mass, is readily decomposed by chlorine when heated, is soluble in strong solutions of iodide of potassium and chlorides of potassium and sodium, scarcely soluble even in strong ammonia. It forms double salts with alkaline iodides, with cyanide of potassium, and, with basic nitrate of mercury, forming the compound $\text{AgI} + 2\text{HgO}, \text{NO}_5 + \text{HO}$.

4. *Fluoride of S.*, AgF , formed by the action of fluohydric acid on carbonate of silver, is soluble, and, when dry, fusible like chloride. Silico-fluoride, $3\text{AgF} + 2\text{SiF}_3$, is soluble and crystallizable, and precipitates as a basic salt by a little ammonia.

OXYLSALTS.

1. *Sulphur. Sulphate of Silver*. AgO, SO_3 . Boil silver powder with $1\frac{1}{2}$ pts. oil of vitriol, or dissolve the oxide or carbonate in dilute sulphuric acid. It may be obtained in crystals from its solution in nitric acid, white, shining,

SILVER.

isomorphous with dry sulphate of soda, soluble in 87 pts. water, more so in nitric acid or oil of vitriol. Dissolved in ammonia it crystallizes out as $\text{AgO}, \text{SO}_3 + 2\text{NH}_3$. When sulphuret of silver is acted on by nitric acid, it forms a brownish yellow oxysulphate or sulphobasic sulphate of silver.

2. *Sulphite of S.*, AgO, SO_2 , precipitates from a solution of nitrate of silver by the addition of sulphurous acid or a sulphite. Hyposulphate or dithionate of silver, $\text{AgO}, \text{S}_2\text{O}_5 + 2\text{HO}$, is obtained from a solution of carbonate of silver in dithionous acid. It also crystallizes with 2NH_3 instead of water from a solution of the salt in ammonia.

Hyposulphite of S. Dithionite of S. $\text{AgO}, \text{S}_2\text{O}_2$. Add moderately dilute nitrate of silver to concentrated dithionite of alkali in excess, wash the gray mixture of dithionite and sulphuret of silver on the filter with cold water, extract the dithionite by ammonia, precipitate it by exact neutralization by nitric acid, filter, and dry rapidly in paper. This salt forms double salts with other dithionites, which are made by dissolving as much freshly-precipitated chloride of silver in a solution of a neutral hyposulphite as it will dissolve, filtering and precipitating the salt by alcohol; the salt is pressed and dried in vacuo, over oil of vitriol. Such is the affinity of oxide of silver for dithionous acid, that it separates half of the alkaline base of an alkaline hyposulphite, and makes a strongly alkaline solution. The double salts, with dithionite of alkali, are crystalline; with strontia, lime, and lead, white powders. They are all characterized by intense sweetness, the salt of ammonia being so sweet as to occasion pain, and imparting a sweet taste to 32,000 pts. water. Trithionite and tetrathionite of silver are whitish and yellow.

2. *Nitrate of S.* Lunar caustic. AgO, NO_3 , containing 68.23 pr. ct. oxide of silver. It is formed by solution of pure silver in pure nitric acid; or by solution of silver coin in nitric acid, evaporation to dryness, and fusion until no green light is perceptible, and a test taken out, dissolved in water, filtered, and the clear solution tested with ammonia shows the absence of copper. A simple and good method is to dissolve coin in common nitric acid, to precipitate by salt or muriatic acid, wash thoroughly, to decompose the chloride by zinc and muriatic acid, to dissolve the silver in nitric (which may contain some muriatic), and to evaporate the clear solution to crystallization or to fusion. The chloride in the last case is kept for the next operation. 1 pt. silver should form 1.575 nitrate of silver.

Prop. Colorless, right rhombic crystals, of spec. grav. 4.3554, of a bitter, metallic taste, poisonous, and caustic to organic matter, which it blackens by the action of light; fuses readily without change of weight to a liquid, which congeals to a white, fibrous mass. It is soluble in 1 pt. cold, in $\frac{1}{2}$ pt. hot water, in 4 pts. boiling alcohol; insoluble in nitric acid. It does not blacken by light, unless organic matter be present; deflagrates on ignited coals, explodes with phosphorus by a stroke; by a low red heat is resolved into silver, oxygen, nitrogen, and red oxide of nitrogen. Lunar caustic is made by fusing the crystals, and casting it into sticks, in a mould.

SILVER.

SMILAX CHINA.

It is largely used in surgery, as a caustic; as an indelible INK, which is removable by cyanide of potassium; for darkening hair by exposure to light, and by the action of sulphur.

Ammonia nitrate of silver, $\text{AgO}, \text{NO}_3 + 2 \text{NH}_3$, crystallizes from a solution of the simple nitrate, in ammonia; it darkens readily by light. There is a crystallizable double salt, with mercury, $\text{AgO}, \text{NO}_3 + \text{HgO}, \text{NO}_3$. Nitrate of silver also forms double salts with cyanides of copper, mercury, and silver, the formula of the last two being 2HgCy (or 2AgCy) + AgO, NO_3 , and the salt of mercury with 8 HO.

Nitrite of S. The neutral salt, AgO, NO_2 , is made by precipitating nitrate of silver by nitrite of soda, washing the precipitate by a little cold, then dissolving it in hot water, from which after filtration it crystallizes; white, soluble in 120 pts. water at 59° ; it may be used to prepare metallic nitrites, by adding it to their chlorides.

The basic salt is formed by boiling silver in a neutral solution of nitrate of silver, and evaporating the yellow solution until very concentrated, when it congeals to a crystalline mass. Water decomposes it into a neutral and more basic salt, which separates as a yellow powder.

3. *Phosphate of S.* The half-basic salt of phosphoric acid is made by dropping common phosphate of soda into a neutral solution of nitrate of silver; a lemon-yellow powder, soluble in acids and in ammonia, separating from the latter in crystalline grains; formula $3 \text{AgO}, \text{PO}_3$. The neutral phosphate, $2 \text{AgO}, \text{PO}_3$, is made by dissolving the basic salt in warm, concentrated phosphoric acid, or by adding an excess of phosphoric acid to nitrate of silver, and evaporating, when it forms large colorless crystals, decomposable by water, leaving the yellow basic salt.

The neutral ^bphosphate, $2 \text{AgO}, \text{PO}_3$, is obtained by adding ^bphosphate of soda to nitrate of silver; a white, fusible salt, insoluble in water. The biphosphate, AgO, PO_3 , of ^bphosphoric acid, is made by adding an ice-cold solution of the freshly-ignited acid to a solution of nitrate of silver; white, gradually losing acid by washing, very fusible a little above 212° ; if heated gradually in water to boiling, it forms a sesqui-subphosphate, $3 \text{AgO}, 2 \text{PO}_3$.

4. *Perchlorate of S.*, AgO, ClO_7 , made direct, is a white powder, deliquescent, and soluble in strong alcohol; fusible, and explosive below a red heat. *Chlorate of S.*, AgO, ClO_3 , also formed direct, forms white, 4-sided prisms, soluble in 5 pts. cold, 2 pts. hot water, and a little in alcohol; much more explosive than alkaline chlorate under like circumstances, and decomposed by acids into oxygen and chloride of silver. By adding ammonia in excess to its solution and evaporating, an ammonia-chlorate, $\text{AgO}, \text{ClO}_3 + 2 \text{NH}_3$, is obtained in crystals. *Chlorite of S.*, AgO, ClO_3 , is obtained by adding an alkaline chlorite with excess of alkali to nitrate of silver, boiling the precipitate with water, and filtering hot; yellow, crystalline scales, explosive at 221° .

5. Bromic acid, or a bromate precipitates from nitrate, the white *bromate* of silver, slightly soluble in water, not in nitric acid, readily in

ammonia; converted into chloride by muriatic acid. A compound with ammonia, is similarly formed to the chlorate.

6. *Basic periodate of S.*, $2 \text{AgO}, \text{IO}_7 + 3 \text{HO}$, is formed by precipitating nitrate of silver by basic periodate of soda, washing with water containing nitric acid, and dissolving in warm, dilute nitric acid, from which it crystallizes on cooling, in shining straw-yellow crystals. If treated with warm water, crystalline water is extracted, leaving $2 \text{AgO}, \text{IO}_7 + \text{HO}$, of a red color. If the nitric solution be evaporated, crystals of the yellow neutral salt separate, AgO, IO_7 , decomposable by water into the basic salts. *Iodate of S.*, AgO, IO_3 , is obtained as a white precipitate, by adding iodic acid or an iodate to nitrate of silver; and in crystals from its ammoniacal solution; scarcely soluble in nitric acid.

7. *Carbonate of S.*, AgO, CO_2 , is obtained by adding alkaline carbonate or bicarbonate to nitrate of silver; pale yellow, slightly soluble in water. Dissolved in ammonia, and precipitated by absolute alcohol, a white ammonia-carbonate is obtained.

8. *Borate of S.*, AgO, BO_3 , is obtained by mixing nitrate of silver with a concentrated solution of borax; white, fusible, soluble in large quantities of water.

SILVER COPPER GLANCE. See STROMEYERITE.

SIMILOR. *Tech.* Gold colored BRASS.

SINAPISIN.

SINAPOLIN. } See MUSTARD SEED.

SINNAMIN.

SIPPEERIN. *Chem.* A vegetable alkali found by Rodie in the bark and seeds of the *Beeberu* tree of British Guiana. It is uncrystallizable and soluble in anhydrous ether. (*Chem. Gaz.* i. 350.) It is said to be very efficacious in checking intermittent fever.

SISMANDIN. *Min.* A mineral allied to chloritoid. $G. = 3.565$. Dark green; yields water; infusible, but becoming brown by heat; effervesces with soda, and shows iron by the fluxes. Form. $4 \text{Fe}_2\text{O}_3, 3 \text{SiO}_2 + 5 (\text{Al}_2\text{O}_3, \text{HO}) (?)$. From Marul, in chlorate-slate.

SIZE. See GELATIN.

SKATE LIVER OIL. Obtained by boiling the livers of the *Raja clavata* and *batis* with water, and skimming off the oil as it rises to the surface. Spec. grav. .928. Is bright yellow, and by repose deposits a white solid, from which it may be separated by decantation. Boiling ether dissolves the oil, but drops the most of it on cooling. One quart gave to Preisser and Girardin 0.18 grms. iodide of potassium, and on this account is considered preferable, as a medicinal agent, to oil from the liver of CODFISH. The three are essentially similar. (*Journ. de Pharm.* 1842.)

SLAG. *Tech.* The fused, earthy matters of an ore and flux. See metallurgy of IRON, COPPER, LEAD, &c.

SLATE SPAR. See CALCAREOUS SPAR.

SMALT. See COBALT.

SMARAGD. See BERYL.

SMILACIN. See SARSAPARILLA.

SMILAX CHINA. *Syn.* China root. According to Reinsch, there may be extracted from 1000 pts. of this root, by ether, 3 pts. of a waxy substance, 4 of a balsamic resin,

soluble in alcohol; by alcohol of 0.876 spec. grav., 28 pts. smilacin (also sugar, tannic acid, a resinous coloring substance, and a few salts); by alcohol of 0.957 spec. grav., 0.957 pts. tannic acid, with salts, a reddish brown coloring substance, and a crystalline body; by cold water, 26 pts. gum, vegetable gelatin, and salts of potash, lime, and manganese; by hot water, 235 pts. starch; by caustic potash, 340 pts. starch, with tannic acid; lastly, 200 pts. vegetable fibre, and 120 water. The admission of a crystalline substance in the alcoholic extract is founded on the formation of a crystalline pellicle during the evaporation of this extract. The aqueous solution contains, besides the ordinary starch which is exclusively present in the cold aqueous and alkaline extracts, also a kind of starch, which is colored reddish brown by tincture of iodine. (*Buchn. Repert.* xxxii., and *Chem. Gaz.* ii.)

SMARAGDITE. An augite and hornblende rock.

SMARAGDOCHALCITE. See ATACAMITE and DIOPTAISE.

SOAPS. *Tech. Lat. Sapo. Fr. Savon. Ger. Seife.* Soaps are chemically considered compounds of the fatty acids with the bases; but in the usual acceptance of the term, soap is the detergent material formed by saponify-

ing fat with alkalis. In this reaction the alkali displaces the natural base of the fat which remains in solution and unites with the eliminated acids. The salts thus formed differ in consistence with that of the grease, and with the nature of the alkali employed. Potassa yields soft and soda hard soaps, but the former may be less flaccid, and the latter firmer, according as the fluid (olein) or solid constituent of the fat predominates. The metallic and the earthy soaps are all insoluble, and therefore have no application for domestic purposes. In Pharmacy, the former are known as plasters. A true and good soap should be a definite chemical compound, and any excess of water, or the presence of saline matters is destructive from its value. Rosin, which is added to white soap to convert it into yellow soap, when not in too large a proportion, may be considered an ameliorator, as it has itself, when combined with alkali, a cleansing power. The quality of the soap might probably be still further improved by substituting for the old plan of smelting the rosin in the hot paste, that of dissolving the latter in a resino-alkaline ley, which process seems to increase the detergency of the soap.

Below is a table of the analyses of several soaps.

Kind of soap.	Fatty acids.	Dry potash.	Dry soda.	Water.	Common salt.	Name of the Analyst.
Castile soap, sp. gr. = 1.0705.....	76.5	—	9	14.5		Ure.
Ditto sp. gr. = 0.9669.....	75.2	—	10.5	14.3		“
Fine white toilet soap.....	75	—	9	16		“
Ordinary white soap from Glasgow..	60.0	—	6.4	33.6		“
Mottled tallow soap of good quality, prepared by an able soap-boiler from potashes, after having been kept for several years.....	81.25	1.77	8.55	8.43		Heeren.
Brown resin soap from Glasgow.....	70.0	—	6.5	23.5		Ure.
London cocoa-nut soap*.....	22.0	—	4.5	73.5		“
Hard poppy-oil soap.....	76	—	7	17		“
French soap— <i>savon en tables blanc</i> ...	50.2	—	4.6	45.2		Thénard.
Marseilles soap— <i>savón marbré</i>	64	—	6	30		“
Ditto.....	60	—	6	34		D'Arcet.
White Marseilles soap.....	68.4	—	10.24	21.36		Braconnot.
White tallow soap, Leipzig, prepared by a company.....	76.3	8.8		14.7		Abendroth.
Ditto, Leipzig, privileged manufactory.....	50	9.4		29.8		“
Marbled soap from the same manufactory.....	45	9.8		38		“
Soap from hazel-nut oil.....	64	7	—	28		—
Soft soap.....	44.0	9.5	—	46.5	1	Thénard.
London soft-soap.....	45.0	8.5	—	46.5		Ure.
Belgian soft, or green soap.....	36	7	—	57		“
Scotch soft-soap.....	47	8	—	45		“
Another kind of good green soap....	34	9	—	57		“
Scotch, soft rape-oil soap.....	51.66	10	—	38.33		“
Scotch, soft olive-oil soap.....	48	10	—	42		“
Semi-hard soap for fulling.....	62	11.5	—	26.5		Verviers.
Ordinary soft soap, 1st sample.....	44	9.5	—	46.5		Chevreul.
Ditto 2d “.....	42.8	9.1	—	48		“
Ditto 3d “.....	39.2	8.8	—	52		“

* This soap, consisting of nearly $\frac{1}{2}$ water, was tolerably hard, but dissolved very easily in boiling water. It is called *marine soap*, and is said to be applicable to washing with sea-water.

Soaps.	Fatty acids { } Resin.	Soda.	Salt.	Lime and insoluble residue.	Water.	Analyst.
Mottled.....	67.5 | —	7.7	—	Traces.	24.2	Morfit.
Colgate's (yellow).....	56.2	9.0	3.8		31.0	"
"Beatty's" (patent)....	37.0	5.5	0.5		52.0	"
"Butterfield's" (")...	22.0 | 10.50	9.25	1.70	2.0	55.0	"
"Nonpareil" (")...	36.2	5.2	5.25		51.9	"

Soft-soaps are made from oils and potassa.

Hard-soaps from tallow or solid fat and soda.

Extemporaneous or "little *Pan-soaps*" are made by the direct combination of the melted fat with alkali of 36° B.

Among the "patent" soaps are "sand," "Dextrine," "galinated" and "poor-man's," each made of ordinary soap paste, dosed while warm with sand, starch, salts, or glue to increase its weight and bulk without proportionably improving its quality.

The properties of the saponaceous compounds are given under BUTYRIN, OLEIN, MARGARIN, STEARIN, COCO and PALM-OIL; and full particulars as to their mode of manufacture are detailed in Knapp's "*Technology*" and Morfit's "*Applied Chemistry*."

SODALITE. *Min.* Cryst. Regular with 12-hedral cleavage; also massive. H. = 6. G. = 2.26—2.30. Brown, gray, blue, vitreous, transparent, subtranslucent; fracture, conchoidal, uneven. It fuses with puffing; fuses with difficulty or only swells up with soda. Decomposed by muriatic or nitric acid, the silica gelatinizing. Probable form. 3NaO , $2\text{SiO}_3 + 2(\text{Al}_2\text{O}_3, \text{SiO}_3)$, with a portion of chloride of sodium. From Greenland and Vesuvius.

SODA SALTPETER. See NITRATE OF SODA.

SODIUM. *Chem. Syn.* Natrium. Natronium. The difference between soda and potassa was shown in the middle of the last century; and H. Davy obtained the metal in 1807. It occurs as chloride of sodium or common salt in sea water, salines, rock salt, and in minuter quantity in almost all spring and well waters; as carbonate in the natron lakes of Egypt, Hungary, &c.; as sulphate in sea water and salines, and as a base in many silicates, feldspar, the zeolites, in stone coal; in the vegetable and animal kingdoms in combination with various organic bodies and with mineral acids. It is therefore the most abundant of the three alkaline elements, and in the form of common salt is found in nearly every part of the globe.

SODIUM AND ITS NON-SALINE COMPOUNDS.

1. *Sodium.* It is prepared exactly like potassium. It is silver-white with a high lustre, crystallizing in cubes; spec. grav. 0.97; rather hard at 4°, malleable at 32°, very soft at 122°, and fluid at 194°; it volatilizes nearly at a red heat with colorless vapor. It oxidizes readily in the air to caustic soda; rapidly on water, throwing off hydrogen and steam, but without ignition. Its inferior affinity for oxygen, compared with potassium, is shown by its decomposing the same acids, oxides, and salts, but with less evolution of heat, and usually at a higher temperature. Sym. Na. Equiv. 23. (289.729 O = 100. Berz.).

2. *Soda.* Oxide of sodium. *Ger.* Natron.

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Dry soda, prepared by burning the metal, is a gray mass, fusible at a strong red-heat, absorbing water powerfully, with evolution of heat. The hydrate or common *caustic soda* is made in the same ways as caustic potassa, employing 2 pts. of the best soda-ash to 1 pt. lime; or 0.48 pts. quicklime to every pr. ct. real alkali by the alkalimeter. It is purified in a similar manner. It is a white, brittle, fibrous mass, fusible and somewhat volatile at a red-heat, but less so than potassa. It dissolves readily in water, evolving heat; 100 pts. water at 64.4° dissolves 60.5 pts. dry hydrate, at 89.6° 73 pts., at 131° 100 pts., at 158° 117 pts., at 176° 127 pts. hydrate (*Osann*). The following table gives pretty closely the percentage of real alkali at 59°, according to the specific gravity of the liquid:—

Sp. gr.	Pr. ct.	Sp. gr.	Pr. ct.	Sp. gr.	Pr. ct.
2.00...	77.8	1.36...	26.0	1.24...	15.2
1.85...	63.6	1.35...	25.0	1.22...	14.0
1.72...	53.8	1.34...	24.0	1.18...	12.0
1.63...	46.6	1.33...	23.0	1.15...	10.2
1.56...	41.2	1.32...	22.3	1.11...	7.8
1.47...	34.0	1.29...	20.0	1.08...	6.0
1.44...	31.0	1.27...	18.0	1.05...	3.6
1.40...	28.5	1.25...	16.3	1.02...	1.2
1.38...	27.0				

Crystallized hydrate separates from solution by a very low temperature. Its causticity and other properties are the same as potassa, but less powerful.

Salts. Soda has a little less affinity for acids than potassa. All its salts are soluble except the silicofluoride. Its salts usually take up a large amount of crystal-water, and are efflorescent. It forms double salts similar to potassa.

Hyperoxide of sodium, formed similarly to that of potassium, is greenish yellow.

2. *Sulphur.* *Sulphuret* of S. NaS, is obtained by passing dry sulphohydrogen over dry caustic soda, or by reducing sulphate of soda by charcoal.

Sulphohydrogen passed through one-half of a solution of soda to saturation, and the two parts mixed together, give a solution of the simple sulphuret, which by evaporation apart from the air yields colorless crystals; of the formula $\text{NaS} + 9\text{HO}$. The other sulphurets are very similar to those of potassium, and are obtained in a similar manner; they are NaS_2 , NaS_3 , NaS_4 , and NaS_5 .

3. *Alloys.* Sodium readily unites with potassium in different proportions, generally yielding brittle, crystalline, silver-white alloys. It unites readily with mercury, producing heat and even light, and forming a brittle amalgam. The best method of preparing an amalgam is to rub 1 pt. sodium with 100 pts. mercury in a

mortar, adding the former portion-wise, and separating the solid from the fluid portion.

HALOID SALTS.

1. *Chloride. Chloride of Sodium.* Syn. Muriate of soda. Common salt. Sea-salt. Rock-salt. *Ger.* Kochsalz. Common salt is prepared by evaporating salt springs, of sufficient strength, by heat, in large iron pans. As the water evaporates, crystals of salt form in the liquid, and are raked out upon the sloping sides of the pan to drain. Sea-water and some salines are first evaporated in shallow wooden vats by the sun heat, and then finished by fire. Some feeble salines are concentrated to stronger brine by evaporation in the air by means of a graduation-house, an oblong and elevated frame-work, covered by a roof, along the top of which is a trough to contain the salt water. The space under the roof is filled up with bundles of twigs. The water is suffered to flow out of numerous openings in the trough upon the fagots, by which it is so divided as to expose an extended surface to the evaporating action of the air, and descends into the receiving reservoir below in a more concentrated form. It is finally crystallized in evaporators. Rock salt is also dissolved in water and the clear solution evaporated, or, where the formation is near the sea, it is dissolved in salt water to a strong brine, which is then evaporated to crystallize. Among the residues in these operations are sulphate of soda, which is used to make soda-ash, sulphate of magnesia or Epsom salt, and a more insoluble residue of sulphate of lime and other salts, which is used in agriculture. The mother liquors of some salines yield a considerable quantity of bromide, others of iodide of sodium. To purify salt, it may be ground or used in fine crystals, thrown on a hopper, and washed with a saturated solution of pure salt. To remove sulphates of soda and magnesia and chloride of magnesium, chloride of barium and carbonate of soda may be used, and the excess of this carbonate then neutralized by muriatic acid.

Prop. NaCl, containing 39.32 sodium+60.68 chlorine. Colorless, crystallizing in cubes, transparent or translucent, usually decrepitate by heat, fusible at a red heat, crystalline on congealing, volatile at a white heat (hence its use in glazing stone-ware). Ignited with silica in a jet of steam, it forms silicate of soda and muriatic acid, $\text{SiO}_2 + \text{NaCl} + \text{HO} = \text{NaO} + \text{SiO}_2 + \text{HCl}$. At the point of volatilization in an atmosphere of steam, it separates into soda and muriatic acid, $\text{NaCl} + \text{HO} = \text{NaO} + \text{HCl}$ (*Tilghman*); and hence the ingenious process of this chemist to manufacture soda from salt. 1 pt. salt is soluble in 2.7—2.8 pts. water (18 equivs.) at every temperature between 32° and 212°. According to Poggiale, 100 pts. of water dissolve 35.52 at 32°, 36.98 at 122°, and 39.61 at 212°.

The saturated solution cooled to 14°, it deposits prismatic crystals, $\text{NaCl} + 4\text{HO}$, which change into cubes in the interior by the slightest causes. Salt is slightly soluble in aqueous, scarcely in absolute alcohol. See EVAPORATION for boiling pts. of solutions of salt.

Salt forms with sulphuric and chromic acids

compounds similar to those of chloride of potassium.

2. *Bromide of S.* NaBr, is similarly made to the potassium salt. It crystallizes in cubes of the dry salt above 86°, and in 6-sided prisms below 86°, with the form. $\text{NaBr} + 3\text{HO}$.

3. *Iodide of S.* NaI. Obtained like the potassium salt. In an impure form it may be obtained from the mother liquors after extracting soda from kelp or varee. Crystallizes in cubes of the dry salt above 100° to 122°, but below that, like the preceding, with 4 HO. Soluble in 0.6 pts. cold water, and in spirits of wine. The dry salt is fusible and volatile by a high heat, but loses a portion of iodine.

4. *Fluoride of S.* NaF, is made direct with fluohydric acid and soda; or by mixing 100 pts. silicofluoride of sodium with 112 pts. carbonate of soda, and a little water, boiling as long as it effervesces, rubbing down the lumps to a paste, again boiling with water, and washing out the fluoride with boiling water. This is evaporated until it opalizes from silica, poured off, evaporated to dryness, again dissolved, filtered, and crystallized. Clear or pearly cubes and 8-hedra, fusible at a high heat, and at a lower heat with silica, soluble in 23 pts. water at 60.8°, scarcely soluble in alcohol. By solution in fluohydric acid and spontaneous evaporation, it yields crystals of the form. NaF, HF

OXYSALTS.

1. *Sulphur. a. Sulphate of Soda.* Syn. Glauber's salt. NaO, SO_3 . Exists ready formed in sea-water and salines, and is obtained from these, and as a residuary product in many processes. It is generally formed by the action of oil of vitriol on common salt, in making soda-ash. When crystallized from a cold, dilute solution, it crystallizes in the common form (oblique rhombic), with the composition $\text{NaO}, \text{SO}_3 + 10\text{HO}$, containing 19.3 pr. ct. soda, and 24.9 sulphuric acid. This salt is fusible at a gentle heat in its crystal-water, part of which it loses. It is soluble in 8.22 pts. water at 32°, in 2.08 pts. at 64.4°, in 1 pt. at 77°, in 0.37 at 89.6°, in 0.31 at 91.4°, in 0.38 at 122.7°, in 0.45 at 144.5°, in 0.44 at 201.2°, in 0.41 at 212°. It is therefore most soluble at 91°, and diminishes above this point, so that a saturated solution at 91°, heated above this point, deposits crystals of the anhydrous sulphate, containing 43.66 pr. ct. soda, and 56.34 pr. ct. sulphuric acid; these crystals are right rhombic. The dry salt is perfectly fusible at a red heat, and by ignition with charcoal is reduced to sulphuret of sodium. The common sulphate (10 HO) fused, yields at 50°, crystals with 8 HO.

Bisulphate is obtained by heating 10 pts. dry sulphate with 7 pts. oil of vitriol. If this be dissolved in 2 pts. hot water, and cooled, crystals are obtained of the composition NaO, $2\text{SO}_3 + 3\text{HO}$.

b. *Dithionate of S.*, or *Hyposulphate*, $\text{NaO}, \text{S}_2\text{O}_5$. Obtained by precipitating hyposulphate of baryta by carbonate of soda, yields right rhombic crystals, soluble in 2.1 pts. water at 61°, in 1.1 pt. boiling, insoluble in alcohol, permanent in the air.

c. *Sulphite of S.* The neutral salt, NaO, SO_2 , formed like the potassa salt, crystallizes with

(10 eq. ?) water, is soluble in 4 pts. cold water, and like the sulphate is most soluble at 91°.

d. Dithionite of S. Hyposulphite. *Prep.* 1. Saturate boiling soda-lye by sulphur, add this to a neutral solution of sulphite of soda, until the mixture appears decidedly yellow, filter, evaporate, cool, and recrystallize the crystals. 2. Through the same soda-lye pass sulphurous acid gas, until a filtered test shows a pale yellow color, evaporate rapidly to a syrup, filter if necessary, add half as much spts. wine in bulk, and let it crystallize in the cold (*Capaun*). 3. Pass sulphurous acid gas through carbonate of soda to make sulphite, dissolve as much sulphur in it as it will take up apart from the air, filter, and evaporate to crystallization (*Capaun*). 4. Prepare sulphuret of sodium so that it is not caked, mix it with charcoal (or reduce sulphate of soda by charcoal), and then moisten it with 20 pr. ct. water, stopping the operation when sulphuretted hydrogen ceases to be evolved. This, dissolved in water, yields at once a good salt on a small scale, but on a manufacturing scale, there should be a slight excess of sulphuret of sodium, to allow of its oxidation during evaporation. If, therefore, a test of the above solution be colorless, it is advisable to add a little sulphuret of sodium, to give it a yellowish tint. The use of alcohol during evaporation prevents oxidation more or less, by forming an atmosphere which excludes the air.

It forms colorless (or yellowish), right rhombic crystals, fusible, very soluble in water, not in alcohol, is permanent in air, and does not react alkaline; its solution changes in close vessels, depositing sulphur, and becoming sulphite; in the air it becomes sulphate of soda, depositing sulphur.

2. *Nitrate of S.* Cubic, or rhombic, or soda-salt-peter. NaO, NO_3 , containing 63.53 pr. ct. dry nitric acid. Found native in Chili and Peru. It crystallizes in obtuse rhombs, fuses by heat, and congeals crystalline; decomposes by heat like nitrate of potassa, is less explosive, when heated with combustibles, than potassa-salt-peter; is decomposed in solution by chloride of potassium or ammonium, and by sulphate of potassa; becomes moist in moist air, whence its inapplicability to powder-making; dissolves in 2.89 pts. water at 35.6°, in 1.14 pts. at 65½°, in 0.77 at 116.6°, in 0.46 at 246°.

Nitrite of S., NaO, NO_2 , is made by heating the nitrate to a certain point, to drive off a portion of oxygen, dissolving in water, crystallizing out unaltered nitrate, and then the nitrite. Rhombic crystals, permanent in air, very soluble in water, insoluble in alcohol.

3. *Phosphates.* *a. Common neutral phosphate of S.*, $2\text{NaO}, \text{P}\text{O}_5$. Exists in urine in considerable quantity. It is prepared purest by dissolving soda in phosphoric acid; less pure by digesting, for 24 hours, 3 pts. burned bones with 2 pts. oil of vitriol diluted with 24 pts. water, straining through linen, washing the sulphate of lime, evaporating, and filtering to rid it of the greater part of sulphate of lime, and precipitating with carbonate of soda. The solution contains phosphate with a little sulphate of soda, which may be separated by crystallization; the solution should have a little excess of carbonate of soda. It forms

oblique rhombic prisms of the form. $2\text{NaO}, \text{P}\text{O}_5, \text{HO} + 24\text{HO}$ (or 26 HO, *Malaguti*), efflorescent, fusible, and losing about 60 pr. ct. = 24 eq. water between 212° and 500°; soluble in 4 pts. cold, and 2 pts. hot water. When it crystallizes above 88°, it contains but 14 eq. crystal water.

b. Neutral pyrophosphate of S., $2\text{NaO}, \text{P}\text{O}_5$. Obtained by igniting *a.*, dissolving in hot water, as oblique rhombic crystals, containing 10 eq. water. It is less soluble than *a.*, has an alkaline reaction, and is not changed into *a.* by boiling with water, but by boiling with the acids, especially nitric.

c. Biphosphate of S., $\text{NaO}, \text{P}\text{O}_5$. Obtained by adding to common phosphate, *a.*, as much more phosphoric acid as it contains, crystallizes from a very concentrated solution in large crystals, with 4 eq. water; very soluble in water, insoluble in alcohol; at 212° 2 HO pass off, a 3d eq. HO passes off between 374° and 455°, between which and ignition the last eq. HO is removed. When heated to lose 3 HO, it precipitates silver salts white, and if dissolved in water and evaporated, forms a crystalline crust, $\text{NaO}, \text{P}\text{O}_5 + \text{HO}$, *bipyrophosphate*. This salt precipitates chloride of barium, may be boiled without passing into *c* biphosphate, and if saturated with carbonate of soda and crystallized, yields *b.* with its 10 HO.

d. Metaphosphate of S. When biphosphate is heated highly to remove all its water, it fuses, and by exposure to air becomes soluble, of neutral reaction, and its solution by evaporation yields a gummy mass, which dries to a hard, gummy substance; it bears ebullition, even with carbonate of soda, for some time without alteration. According to Graham, it is metaphosphate of soda, $\text{NaO}, \text{P}\text{O}_5$, but according to the late views of Berzelius, it is $\text{PO}_5 + 2\text{NaO}, \text{P}\text{O}_5$, or pyrophosphate, with anhydrous phosphoric acid as a pairing or conjugate. When biphosphate is heated only to 600°, it changes into a white, insoluble powder, which is a combination of the above metaphosphate with bipyrophosphate, and the probable formula is $(\text{NaO}, \text{P}\text{O}_5 + \text{HO}) + (2\text{NaO}, \text{P}\text{O}_5 + \text{PO}_5)$. *Berzelius.*

e. Basic phosphate of S., $3\text{NaO}, \text{P}\text{O}_5$. Obtained by adding caustic soda to the common phosphate, and crystallizing; also from the residual liquors after crystallizing out yellow prussiate of potash; rhombic and 6-sided prisms, with 24 eq. water, slightly efflorescent in dry air (*J. C. B.*), soluble in 5.1 pts. water at 60°; the solution absorbs some carbonic acid from the air.

f. Phosphate of soda forms a double salt with that of potassa, of the form. $2\text{KO}, \text{PO}_5 + 2\text{NaO}, \text{PO}_5 + 17\text{HO}$. Phosphate of soda and ammonia (microcosmic salt) is abundant in urine, and is best prepared by mixing 6—7 pts. cryst. phosphate of soda with 2 pts. water, fusing, then dissolving in it 1 pt. finely powdered salammoniac, straining, and setting aside to crystallize. It is recrystallized from solution in water, with the addition of some ammonia. It contains 9 eq. water, loses some water and ammonia in the air, and by fusion forms a clear glass of biphosphate of soda.

g. Phosphite of S., $2\text{NaO}, \text{PO}_3$, forms rhombs, almost cubes, very soluble in water and alcohol.

h. Hypophosphite of S., NaO , PO , obtained from the lime-salt and carbonate of soda, forms deliquescent crystals in vacuo, soluble in water and alcohol.

4. *a. Chlorate of S.*, NaO , ClO_3 , obtained like the salt of potassa, or by boiling 9 pts. chlorate of potassa and 7 pts. silicofluoride of sodium with water, and evaporating the solution; crystals of the regular system $\frac{1}{2}$ 8-hedra (or tetrahedra); behaves like the salt of potassa by heat, is soluble in 3 pts. cold water, in 34 pts. spts. of wine.

b. Perchlorate of S., NaO , ClO_7 , obtained direct, or by heating the chlorate with nitric acid, forms deliquescent rhombs, soluble in alcohol and water.

c. Chlorite of Soda mixed with chloride of sodium, obtained like the salt of potassa, and termed *Labarraque's liquid*. It may be made by dissolving 39 lbs. cryst. soda in $19\frac{1}{2}$ galls. water, and passing through it chlorine derived from 9 lbs. common salt, 7 lbs. manganese, 9 lbs. oil of vitriol, and 7 lbs. water. The simplest process is to decompose a solution of chloride of lime by carbonate of soda as long as carbonate of lime precipitates, and add a little excess of alkali. It is a bleaching liquid, but is generally used as a purifier of unwholesome air.

5. *Bromate of S.*, NaO , BrO_5 , is a dry, crystallizable salt, soluble in 2.7 pts. water at 59° .

6. *a. Iodate of S.*, NaO , IO_5 , is obtained like the salt of potassa. A hot solution yields anhydrous crystals above 158° ; when it begins to crystallize at 68° , it yields first 8-hedral crystals with 6 HO, then prisms with 4 HO, and finally needles with 2 HO. A hot, saturated solution cooled below 41° gives crystals with 10 HO. By saturating caustic soda with iodine, and keeping the solution below 59° , a double salt separates, NaO , IO_5 + NaI + 20 HO. A similar salt with chloride is sometimes obtained, of the composition NaO , IO_5 + NaCl + 12 HO. By evaporating iodate with free iodic acid, a biniodate is obtained, and by treatment with nitric acid, a tritiodate.

b. Periodate, 2 NaO , IO_7 , is obtained as a basic salt, by passing chlorine through 1 pt. iodine in 10 pts. water, neutralizing with 7 pts. dry carbonate of soda, and evaporating nearly at 212° . Behaves similarly to the salt of potassa, and contains, when crystallized, 3 eq. HO. When saturated with periodic acid, anhydrous, neutral periodate crystallize out, with the formula NaO , IO_7 .

7. *Carbonate of Soda*. Syn. Soda, Mineral alkali, Barilla, Kelp, Soda-ash. It is now almost exclusively made by the decomposition of sulphate of soda, and the latter from common salt and oil of vitriol.

PREPARATION OF SODA.

1. *Preparation of Sulphate of Soda*. Powdered common salt is thrown upon the hearth of a reverberatory furnace already heated, and a fine stream of sulphuric acid of spec. grav. 1.6 (56° Beaumé), or the acid of the sulphuric chamber, 52° B., allowed to flow on it through a tube in the roof of the furnace. Fumes of muriatic acid escape into the condensing chamber or pipes, filled with moistened coke, the

use of which is to condense the gas and form liquid muriatic acid. Where a concentrated sulphuric acid is used, the decomposition is performed in an iron tray on the furnace hearth; but with a feeblar acid, lead is used. When the mass of salt is converted into sulphate, it is raked on to hearths where it is more highly heated to expel the last portions of muriatic acid, and dry the whole thoroughly to *salt-cake*. Or it is raked through openings in the hearth, into an enclosed space beneath. The theory of the process is simply the use of 1 eq. oil of vitriol to 1 eq. common salt, thus, $\text{NaCl} + \text{SO}_3, \text{HO} = \text{NaO}, \text{SO}_3 + \text{HCl}$. Therefore, to every 100 pts. common salt, 85 pts. commercial oil of vitriol are required (or 130—135 pts. acid from the chambers). 62 pts. dry muriatic acid are obtained, and about 115 pts. sulphate of soda. The charge of a furnace is from 3 to 8 cwt. of common salt.

2. *Decomposition of the Salt-cake*. 100 pts. of the salt-cake, 55 charcoal, and 100 to 120 pts. chalk are powdered, sifted, and thoroughly mixed. The mixture is placed upon the upper hearth of a reverberatory, heated, and when it begins to soften, is raked down on the next lower hearth, where a higher heat effects the decomposition, and fuses the whole. It is then raked out, and solidifies. It is crude or ball-soda, and consists chiefly of carbonated and caustic soda $\frac{1}{3}$, of sulphuret of calcium $\frac{1}{3}$, and carbonate of lime $\frac{1}{3}$, the remainder being charcoal, sulphate and muriate of soda, water, sand, &c. 100 pts. sulphate or salt-cake yield 153—168 pts. ball-soda, containing 50—55 pts. dry carbonate of soda, instead of 75 pts. which it should contain by theory. The changes in the process are twofold:—1st, the decomposition of the sulphate by charcoal, forming sulphuret of sodium and carbonic oxide, the latter escaping as gas; $\text{NaO}, \text{SO}_3 + \text{C}_4 = \text{NaS} + 4 \text{CO}$. 2d, the action between carbonate of lime and sulphuret of sodium, forming carbonate of soda and sulphuret of calcium; $\text{NaS} + \text{CaO}, \text{CO}_2 = \text{NaO}, \text{CO}_2 + \text{CaS}$. But if the lime has become partly caustic, caustic instead of carbonate of soda will be formed. If the ball-soda were made by these proportions, then a solution of carbonate of soda and sulphuret of calcium would mutually return into their former combination of sulphuret of sodium and carbonate of lime. But twice the quantity of lime is used as the formulas indicate, and this becoming caustic, unites with the sulphuret of calcium, forming an oxysulphuret of calcium, which will not immediately decompose carbonate of soda under water. The changes here represented successively take place simultaneously, and may be thus represented, $2(\text{NaO}, \text{SO}_3 + \text{C}_3 + 3(\text{CaO}, \text{CO}_2) = [2(\text{NaO}, \text{CO}_2) + 2 \text{CaS}, \text{CaO}] + (8 \text{CO} + \text{CO}_2)$. The carbonate of soda and oxysulphuret of calcium together constitute the crude soda; the carbonic acid and oxide escape as gases.

3. *Preparation of Soda-ash*. The crude soda is placed in iron boxes perforated with holes, which are suspended in iron cisterns, just below the top of the liquid. A series of these cisterns is placed side by side, one a little below the adjoining one. A stream of fresh water enters the uppermost cistern, and flows out through a pipe leading from near its bottom to

the top of the next lower cistern, the temperature of the whole being maintained at about 100°. The boxes being placed near the top of the liquid, the heavy solution sinks to the bottom, and is carried by the pipe to the next lower cistern. The boxes containing fresh crude soda are placed in the lowermost cistern, and successively transferred to the higher ones, where they meet a less saturated solution, until in the highest they are exhausted by fresh water, and oxysulphuret of calcium remains. The lye of the lowest cistern being concentrated, is partly evaporated in leaden pans, during which the crystals of soda falling to the bottom, are raked out and drained. The remaining liquor, containing caustic soda and sulphuret of sodium, is evaporated to dryness, mixed with charcoal or sawdust, and heated to redness in a reverberatory, whereby the sulphuret is decomposed, and the whole changed into carbonate. Another process, is to evaporate the strong lye directly to dryness in iron pans, and heat it with charcoal or sawdust. To prepare a purer soda, the half-purified soda is redissolved, evaporated, and crystallized in iron pans. The soda, whether from crystals or direct evaporation, heated in a reverberatory, become dry and burn whiter, and constitute the soda-ash of commerce. According to the amount of purification and care in the manufacture, soda-ash consists of a mixture of carbonate and caustic soda, equivalent to from 60 to 90 pr. ct. of carbonate. The standard of good soda-ash in our market is 80 pr. ct. carbonate, calculated both from caustic and carbonated soda.

For the method of testing soda-ash, see ALKALIMETRY. The principal uses of soda are for SOAP-boiling and in GLASS-making.

a. Carbonate of S. crystallizes at a low temperature in the form. $\text{NaO}, \text{CO}_2 + 10 \text{HO}$, containing 21.68 pr. ct. soda, 62.94 water, and 15.38 carbonic acid. It is soluble in 2 pts. cold, and less than 1 pt. hot water. The content of dry carbonate at 59°, is shown in the following table:—

Sp. grav.	Pr. ct.	Sp. grav.	Pr. ct.
1.182	14.88	1.085	7.44
1.165	13.76	1.076	6.40
1.150	12.65	1.063	5.58
1.131	11.16	1.049	4.46
1.112	9.67	1.041	3.72
1.098	8.56	1.020	1.85

It effloresces in the air, losing $\frac{1}{2}$ of its water, and retaining 5 eqvs. When heated above 100°, it loses 9 eq. water, and the same salt crystallizes from the leaden pans in evaporating the soda-lye, as above stated. Evaporated above 60°, it crystallizes with 8 eq. water. The dry salt is alkaline, more feeble than that of potassa, and fuses more readily.

b. Sesquicarbonate of S., obtained by boiling a solution of bicarbonate, crystallizes with the formula $2 \text{NaO}, 3 \text{CO}_2 + 4 \text{HO}$.

c. Bicarbonate of S. is obtained by passing carbonic acid over carbonate of soda, containing an equiv. water. The best degree of moisture may be attained by efflorescing the crystallized soda in warm air, or by mixing 4 pts. of this with 1 pt. crystallized. It may also be made by passing the gas into a concentrated

solution of carbonate. It may be obtained in crystals, but is generally used as a dry-feeling powder, of the form. $\text{NaO}, \text{CO}_2 + \text{HO}$, containing 37 pr. ct. soda, and $10\frac{1}{2}$ water.

8. *Oxalate of S.* *a. Neutral.* Made by neutralizing soda with the acid, is not very soluble; crystalline, and is anhydrous. *b. Acid.* Made by adding 1 eq. carbonate of soda to 2 eq. oxalic acid, is difficultly soluble, and has the form. $\text{NaO}, \text{HO}, 2 \text{C}_2\text{O}_3 + 2 \text{HO}$.

9. *Borates.* *a. Neutral.* Made by heating 1 eq. dried borax (biborate of soda) with 1 eq. carbonate of soda; is very soluble in water, from which it crystallizes with a form. $\text{NaO}, \text{BO}_3 + 8 \text{HO}$. When fused in its crystal-water, it long remains fluid even at 32°, and crystals form in it with 6 HO. It is decomposed by the carbonic acid of the air, both solid and in solution, into borax and carbonate of soda.

b. Biborate. Syn. Borax, Tincal. Is manufactured from native boracic acid, which is found in small lakes in Tuscany. Jets of vapor issue from below the surface of the earth in Tuscany, in a district extending over some 40 miles, and bring up with them various gases, carbonic acid, nitrogen, oxygen, and sulphohydrogen, with ammonia, boracic acid, sulphates of lime, alumina, and iron, &c., which condense in ponds of water on the surface of the earth, while the gases escape. The temperature of the jets is about 212° and less. Artificial basins, of 30 to 300 ft. diameter, are constructed around the suffioni, and arranged in terraces on the hill-side. Fresh water admitted to the upper basin is charged by its suffioni, then passed to the next lower to receive a second charge, and so through a series of 6—8. The liquid from the lowest, containing 1—2 pr. ct. boracic acid, is passed to a large cistern or clarifier, from which it passes to a second, and thence to the evaporating pans. These are shallow leaden pans, arranged in terraces, 4 in the upper, 2 in the middle, and 1 below, and are heated by suffioni vapors conducted under them. When $\frac{1}{2}$ the liquid of the upper 4 pans is evaporated, it is transferred to the 2 next, where it is again evaporated one-half, and transferred to the lowest for further concentration. The strong liquid of the lowest pan is now transferred to lead-lined boxes of wood, to crystallize. The crude and dried acid thus obtained, contains about 75 pr. ct. cryst. acid, and 25 pr. ct. sulphates of various bases. The produce of the Tuscan Lagoons, in 1846, was 3,000,000 lbs. crude acid. To every 100 lbs. of crude acid, 120 lbs. cryst. carbonate of soda are employed, the latter being first dissolved in water and the mother-liquor of previous crystallizations, by the aid of a steam-pipe in the liquid, and the acid added in portions of 10 lbs. When the liquid is neutralized, it is allowed to settle for 12 hours, and then drawn off into crystallizers, where the temperature does not fall below 92°, and prevents other salts from separating. The crude borax is redissolved in water, and crystallized, finishing at about 80°. If a saturated solution be crystallized below 130°, common borax forms, in oblique, rectangular prisms, composed of $\text{NaO}, 2 \text{BO}_3 + 10 \text{HO}$, with 47 pr. ct. water; if crystallized between 174° and 130°, octahedral borax is obtained, with the

form. NaO , $2 \text{BO}_3 + 5 \text{HO}$, or 30 pr. ct. water. Common borax has an alkaline reaction, is soluble in 12 pts. cold, and 2 pts. boiling water, effloresces superficially in the air, swells up when heated, from loss of water, and fuses by higher heat to a clear glass.

c. Acid borate of S. is obtained by adding boracic acid to borax until it ceases to have an alkaline reaction; it forms tabular crystals.

10. *Silicate of S.* 1 eq. silica fuses readily with 1 eq. carbonate of soda, expelling the carbonic acid, and forming a soluble glass. By dissolving silica in soda-lye until the dry soda and silica are in equal quantity, evaporating, and setting aside, it forms a crystalline mass of the form. 3NaO , $2 \text{SiO}_2 + 27 \text{HO}$, and also with 18HO . For other silicates of soda, see GLASS.

SOIL. See AGRICULTURE.

SOLANIN. *Chem.* Found in several species of *Solanum*, and in the germs of Irish POTATOES. Formula $\text{C}_{84}\text{H}_{68}\text{NO}_{28}$? (*Blanchet*). In feathery crystals, of a pearly lustre and acid taste, very poisonous, soluble in hot alcohol, but insoluble in water. Among its crystalline salts are the sulphate, mucate, tannate; of the non-crystalline are the formate, prussiate, gallate, citrate, and tartrate.

SOLDER. *Tech.* See ALLOY, pp. 120, 121.

SOLID. *Phys.* One of the three states of bodies in which the cohesive force predominates. In liquids the cohesive and repulsive forces are nearly in equilibrium. See GAS.

SOLUTION. *Chem.* The union of a solid, liquid, or gas with a liquid, in which it disappears or becomes liquid. For the solution of a gas, see ABSORPTION. One liquid may mix with another in every proportion, water and alcohol, alcohol and ether; or it may dissolve a certain portion of another, thus, water dissolves a little ether, and ether a little water, alcohol dissolves about $\frac{1}{4}$ spts. terpentine; or they may not mix together at all, as oil and water. The union is sometimes accompanied with evolution of heat, as sulphuric acid and water,—but this may be due to chemical union.

Solids disappear in water, as salt and sugar in water. Since the solution of a solid is heavier than the solvent, this heavier solution remains at the bottom of the solvent, and it is necessary to stir it to expose fresh portions to the action of the solvent; or solution may be effected by keeping the solid at the top of the solvent, when the heavy solution will spontaneously descend. Since the solvent only acts upon the surface of a body, increase of surface by pulverization hastens solution. As a general rule, a hot solvent dissolves more, and more rapidly than a cold, and hence heat is usually employed to hasten solution. The density of a solution is generally greater than the mean of the two bodies, the solvent and the substance dissolved.

That it is not chemical affinity which unites the two bodies, is observed from the saturating point. When water has dissolved a certain quantity of a solid, it ceases to dissolve any more, and the solution is said to be saturated. The quantity dissolved, compared to that of the solvent, indicates no atomic proportions; and, moreover, this quantity may be usually varied by heat and cold. There is but a partial change of properties, the cohesive force

of the solid only being overcome, while its taste, odor, and color remain, although diluted. By heating a solution, the solvent can be dissipated, and the unaltered solid regained. Solution is not like common, heterogeneous adhesion, for in the latter the cohesive force of neither body is affected, it being merely an adhesion of surfaces. The cohesive force of the solvent appears to be increased, for solutions have usually a higher boiling point than the solvent, while the same force of the solid has disappeared. It seems as if a portion of the cohesion of the solid had been transferred to the liquid, and the rest destroyed.

The phenomena of solution, therefore, present a peculiar kind of attraction, referrible to no other. It is true that some have referred it to capillary action, the particles of the solid inserting themselves in the spaces between the particles of liquid, as in a series of capillary tubes; but the destruction of the cohesive force of the solid, sufficiently marks the difference.

The following tables, of solubility in water and in acids, of the simple salts of those oxides and acids which are of frequent occurrence, will be found convenient to the student. *J. C. B.*

1. Salts of alkalies are nearly all soluble in water, except neutral and acid silicates.
2. Solubility of salts in water, except the alkaline salts.

	Soluble.	Partly Soluble.	Insoluble.
Nitrates.....	all		
Acetates.....	all others	Hg_2 , Ag	
Chlorides....	all others	Pb	Hg_2 , Ag
Sulphates....	all others	Ca	Pb, Sr, Ba
Phosphates..	.....	.....	all
Carbonates..	.....	.....	all
Oxalates.....	.....	.....	all (almost)

3. Solubility of phosphates, oxalates, and carbonates in nitric or muriatic acid.

- a. All carbonates soluble with effervescence.
- b. All oxalates soluble.
- c. All phosphates soluble, and reprecipitable by ammonia, unchanged.

SOLVENT. *Chem. Tech.* The term applied to the fluid body employed for the SOLUTION of a substance.

SOMNITE. See NEPHELIN.

SOOT. The condensed smoke formed by the imperfect combustion of organic matter. It consists chiefly of carbon, but contains, besides, empyreumatic vapors and gases varying in properties with the nature of the fuel or material whence generated.

SORDAWALITE. *Min.* Massive. H.=2.5—3. G.=2.53—2.58. Grayish or bluish black; vitreous; opaque; brittle with conchoidal fracture and liver-brown streak. It yields water; fuses on coal to a black bead; with little soda fuses, and with more it only swells; the fluxes show iron and silica; imperfectly decomposed by acids. It seems to be 3RO , $2 \text{SiO}_2 + \text{Al}_2\text{O}_3$, 2SiO_3 with hydrous phosphate of magnesia 2MgO , PO_5 . From Sordawala in Finland, and Bodenmais, Bavaria.

SPADAITE.

SPADAITE. *Min.* A talcose mineral allied to SCHILLERSPAR, PICROSMIN, &c. It yields water in a tube, fuses to an enamel, and is easily decomposed by muriatic acid. Form. 4 (MgO, SiO₂) + MgO, 4 HO. From Capo di Bove.

SPARRY IRON. *Min.* Syn. Carbonate of iron, Spathic iron, Brown Spar, Sphærosiderite, Junkerite. *Ger.* Spatheisenstein, Eisen-spath, Stahlstein; the earthy variety, Clay-iron-stone. Cryst. Hexagonal, rhombic, the faces often curved; also fibrous, massive, granular. H. = 3—4.5. G. = 3.7—3.83. Color gray, yellowish and greenish, brown; the earthy also bluish gray; lustre vitreous, pearly; translucent, the earthy also opaque; brittle with uneven fracture and white streak.

Blackens by heat, and becomes magnetic; shows iron and often manganese, with the fluxes; soluble in acids with effervescence. Form. FeO, CO₂, in which a portion of iron is often replaced by Mn, Mg, Ca. Alumina and silica are usually present in clay-iron-stone. See Metallurgy of Iron, *d.*, p. 730. The following table of analyses will convey an idea of the composition of sparry ores:—

	1.	2.	3.
Oxide of iron.....	55.25	63.75	48.20
“ “ manganese. 3.75	0.75	7.07	
Lime	0.50	—	0.67
Magnesia	0.75	0.25	1.84
Carbonic acid.....	35.00	34.00	38.22
	95.25	98.75	96.00
	4.	5.	6.
Oxide of iron.....	36.81	48.93	52.17
“ “ manganese. 25.31	—	—	—
Lime and magnesia..	—	2.40	—
Carbonic acid.....	38.35	20.20	31.83
Silica.....	—	23.75	16.50
Alumina.....	—	2.25	—
	100.47	97.53	100.50

No. 1. is crystallized from Kemlas in Bai-reuth; 2. Sphærosiderite from Steinheim near Hanau, both by Klaproth; 3. from Stolberg, by Stromeyer; 4. from Ehrenfriedersdorf, by Magnus; 5. from Pottsville, Pennsylvania, by J. C. B.; 6. from Durham on the Delaware, below Easton, by J. C. B. The first four are true sparry ores; the last two are clay-iron-stone, of which 5. is from the anthracite coal measures, and 6. from a clay bed, either diluvial or upper secondary. Sparry ore is associated with rock formations of all ages. The large beds or veins in Styria, &c., are connected with gneiss; clay-iron-stone occurs both in nodules imbedded in slate, and also in connected regular strata in the coal measures of England, U. States, and wherever coal has been found. In England, it yields a large proportion of the iron of commerce.

SPARRY MANGANESE. See MANGANESE SPAR.

SPEAR PYRITES. See IRON PYRITES.

SPECULAR IRON. *Min.* Syn. Red Hematite, Red Iron Ore, Micaceous Iron Ore, Red Ochre, Rotheisenstein, Rotheisenerz, Blutstein, Eisenglanz, Fer Oligiste. Cryst. Hexagonal, rhombic; also imitative forms, fibrous, foliated

SPINELL.

and micaceous, granular, earthy. H. = 5.5—6.5. G. = 4.3—5.3. Color of the highly crystalline and micaceous, steel-gray and iron-black; of the fibrous and less compact, red and brownish red; lustre of crystalline, metallic or sub-metallic, splendid and shining; of others, sub-or non-metallic, glimmering and dull; usually opaque, rarely translucent with a red color; streak of all varieties red or brownish red; sometimes magnetic. It behaves like oxide of iron before the blowpipe, sometimes giving a little water. It is essentially peroxide of iron, Fe₂O₃. See Metallurgy of Iron, *b.*, p. 730.

Specular iron occurs in nearly all geological formations, the highly crystalline more frequently among primary and metamorphic rocks, as the large formation at the Iron mountains, in Missouri. Another large formation of a siliceous variety, are the regular beds in the variegated shales of the lower secondary rocks, known in Pennsylvania as the Danville ore. In the latter beds, and in newer sedimentary formations, it also occurs black, metallic, and crystalline.

SPECULUM METAL. See ALLOY.

SPEISS. The artificial crude Arseniuret of NICKEL, obtained in the manufacture of Smalt, from roasted COBALT ores.

SPEISS-COBALT. See ARSENICAL COBALT.

SPELTER. The commercial name for ZINC.

SPERMACE. *Chem. Tech.* A substance contained in the head of the *Physeter Macrocephalus*. Fresh from the whale it is suspended in oil, from which it is separated by pressure in bags. See CETYL.

SPHÆROSIDERITE. See SPARRY IRON.

SPHÆROSTILBITE. See STILBITE.

SPHÆRULITE. Globules of OBSIDIAN.

SPHENE. *Min.* Titanite, Menachan-ore, Silico-calcareous oxide of titanium, Lederite, Greenovite. Cryst. Oblique rhombic. H. = 5—5.5. G. = 3.24—3.47. Yellow, green, gray, brown, black; lustre adamantine resinous; transparent, opaque; brittle, with white streak. It fuses on the edges with some puffing, to a dark glass; dissolves in borax with a yellow color; dissolves with difficulty in mic. salt, and the addition of tin in the reducing flame shows titanium. Imperfectly decomposed by muriatic acid; better by oil of vitriol, or by fusion with carbonate of soda, or bisulphate of potassa; and best of all by fluohydric acid. Formula, according to H. Rose, 3 CaO, SiO₂ + 3 TiO₂, SiO₃; according to Berzelius, 2 (CaO, SiO₂) + CaO, 3 TiO₂. Sphene occurs in primary rocks in numerous localities, but rarely in masses. A brownish yellow variety occurs in gneiss, about 1 mile from Fairmount on the Schuylkill, near Philadelphia.

SPINELL. *Min.* Ceylonite, Pleonast, Almandine Ruby, Rubicelle, Candite, Hercinite. Cryst. Regular, Pl. VIII. figs. 1, 2, 3, 6, 9, 11, and their combinations. H. = 8. G. = 3.52—3.59. Hercinite, 3.9. Red, blue, green, yellow, whitish, brown, black; lustre vitreous, from splendid to glimmering; transparent, subtranslucent; fracture conchoidal, and streak white. Unaltered by heat, but some show changes of color; the fluxes show iron, and with some also chrome; some form a slag with soda, others not. Easily decomposed by fusion with bisulphate of potassa. Formula, MgO,

(FeO), Al_2O_3 , or the general formula $\text{RO}, \text{R}_2\text{O}_3$, therefore isomorphous with magnetic and chromic iron, franklinite, &c. Spinells of beautiful colors are found in Ceylon and other parts of the E. Indies. Spinells in variety and abundance occur in the great mineral range from Amity, Orange Co., N. York, to Andover, N. Jersey. The prevailing color in this locality is dark green, in which $\text{RO} = \text{MgO}, \text{FeO}, \text{CaO}$, and $\text{R}_2\text{O}_3 = \text{Al}_2\text{O}_3, \text{Fe}_2\text{O}_3$. The Fe_2O_3 occurs in chlorospinell from Slatoust, in the Ural, and hercinite from Konsperg, in Bohemia, is almost $\text{FeO}, \text{Al}_2\text{O}_3$.

SPINELLAN. See HAUYNE.

SPIRÆ ULMARIA, Oil of. *Chem.* A yellow liquid not pre-existing in the plant, but generated by fermentation during the distillation of the flowers with water. It consists of hyduret of SALICYL, which separates in crystals after some weeks' exposure to 0° – 4° , a crystallizable camphor and two other volatile oils. (*Pagenstecher.*)

SPIRYLIC ACID. See SALICYL.

SPODUMEN. *Min.* Triphan. Foliated, cleaving into rhombic prisms. $H. = 6.5$ – 7 . $G. = 3.11$ – 3.19 . Grayish green, greenish white; pearly; translucent, subtranslucent; uneven fracture and white streak. It yields a little water in a tube; on coal it fuses with puffing; it dissolves with difficulty in borax, more readily in mic. salt, leaving silex; it fuses with soda to a glass; fused with bisulphate of potassa and fluor spar, it colors the flame red, from the presence of lithia. It is scarcely attacked by acids, except the fluoric. Form. $3(\text{NaO}, \text{LiO}, 2\text{SiO}_3) + 4(\text{Al}_2\text{O}_3, 2\text{SiO}_3)$. From Sweden, Tyrol, and several localities in Massachusetts and Connecticut.

SPONGE. *Fr.* Eponge. *Ger.* Schwamm. The cellulous, fibrous tissue found adhering to rocks at the bottom of the sea, and deposited by numberless small animals called Polypi. During vitality, it is imbued with a semi-gelatinous humor, which disappears after death. When impregnated with chlorocalcium, it no longer subsequently swells to the same extent with water. Sponge may be heated to 355° – 390° without any appreciable change, except the loss of elasticity, owing to the expulsion of moisture, its toughness not being impaired. The formula for sponge purified by ether, alcohol, and dilute acid, is $\text{C}_{96}\text{H}_{75}\text{N}_{13}\text{O}_{44}$ (*Liebig's Ann.* xlv. 192). According to Crookewit (*Berz. Rep.* xxiv. 704), sponge consists, like silk, of one substance, Mulder's *Fibroin*, with the formula $\text{C}_{39}\text{H}_{31}\text{N}_6\text{O}_{17}$; and 20 eqs. of fibroin are united with 1 eq. of iodine, 3 eqs. sulphur, and 5 eqs. of phosphorus. The ashes, forming 3.5 pr. ct., contain, according to Possett's analysis, silica, iron, phosphate, sulphate and carbonate of lime, and iodide of potassium.

SPUNK. *Syn.* Amadou. A combustible substance used as tinder, and made by soaking the spongy fungi of the *boletus ignarius* in a solution of saltpeter.

SQUILLS. *Pharm. Chem.* The bulbs of the *Scilla maritima*, containing volatile, saccharine and greasy matters, gum, resin, tannin, citrate of lime, and scillitin.

Scillitin. Lebourdais (*Ann. de Chem. et de Phys.* 1848, and *Chem. Gaz.* vi. 445) prepared it by the following method:—

"A concentrated, highly-colored, and viscous decoction of the bulbs of squills is to be precipitated by acetate of lead (the viscosity of the liquid preventing the precipitation of the animal charcoal), and filtered. The resulting liquid is then agitated in the cold with animal charcoal, and the vessel containing the mixture set aside; gradually the animal charcoal subsides, and carries down with it the bitter and coloring principles; the liquid is now to be decanted, and the charcoal washed, dried, and treated with hot alcohol, which becomes excessively bitter. After filtration the alcohol is removed by distillation, when a milky liquid remains in the retort, in which float numerous minute particles of a whitish substance, sparingly soluble in water, to which it nevertheless imparts an intense bitter taste; it dissolves readily in alcohol, and the solution leaves an amorphous residue on spontaneous evaporation. The milky liquid evaporated in the hot chamber, gives the same result. The substance is neutral, does not absorb moisture from the atmosphere, and produces on the tongue a sensation analogous to that caused by a caustic substance. Scillitin, as thus obtained, is solid, is readily decomposed by heat, dissolves in concentrated sulphuric acid, and appears to communicate to the solution a purple color, which instantly disappears and turns black, owing to decomposition. It is also dissolved by nitric acid, but decomposed at the same time."

STALACTITE, STALAGMITE. *Geol.* The solid deposit of carbonate of lime, formed by the dripping of calcareous waters in caves and cavities in rocks. It is usually crystalline, the pendent stalactites being columnar or fibrous, and radiating from the centre of the pendent column. A stalagmite is the broad sheet or lump formed on the floor or sides of the cave. When the waters are differently colored at different periods, the deposit presents concentric layers of different colors, as in those from the Rock of Gibraltar. Other substances, besides carbonate of lime, assume the stalactitic form, such as oxide of iron (pipe-ore), oxide of manganese, and many silicates.

STANNATES. }

STANNIC ACID. } See TIN.

STANZAITE. See ANDALUZITE.

STAPELIA. According to Fr. J. Bernays, the juice of *Stapelia hirsuta*, as well as several other species of this genus, contains a peculiar bitter substance, which tastes very much like aloes. The author made an incision on a specimen, and obtained in a few minutes a watch-glass full of a mucus, limpid juice, which soon dried in a warm place to a clear gum, full of fissures, and had an acid reaction in its fresh state.

This dry juice is amorphous, like gum-arabic, transparent, shining, pulverizable, not altered by exposure to the air, is void of smell, and has a very permanent bitter taste. Alcohol dissolves out the greater portion, leaving white, tasteless flakes as a residue, which dissolves in water for the greater part. The alcoholic solution on mixing with water becomes milky, and leaves, on evaporation, a bitter substance, shining like varnish, and of which the author swallowed from 3 to 4 grs. without any evil consequences being observed.

Ether dissolves from one-fifth to one-sixth of the juice; and on driving off the solvent, a yellowish, transparent, easily-pulverizable substance, of very bitter taste, remains. This bitter principle of *Stapelia* fuses readily on the application of heat, and burns with a smoky flame without residue, diffusing an odor resembling very much that of burning horn, from which, according to Buchner, we may suppose the presence of nitrogen.

What the ether leaves undissolved is for the greater part taken up by alcohol, and on evaporation of the alcohol a resinous, shining residue is left, the external characters of which scarcely differ from that prepared with ether; but this constituent, insoluble in ether and soluble in alcohol, does not melt on being heated, but puffs up, and leaves an ash on combustion. The bitter principle not only dissolves in ether and alcohol, but also in water. The aqueous solution has a neutral reaction, and yields with solution of potash a flocculent precipitate. (*Buch. Rep.* xxxviii., and *Chem. Gaz.* iii.)

STAPHYSAIN. See DELPHIN.

STARCH. *Chem. Tech.* Syn. *Fecula*, *Amidin*, *Amylin*. The feculent matter of plants, and existing in all parts, though to a greater extent in some than in other portions. It is, however, rarely found in the stem and branches of the dicotyledonous plants; is always contained in the cavities of the cellular substance perfectly isolated, but surrounded by an aqueous liquid. The gluten and other substances with which it is associated, are separable by chemico-mechanical means. All that is used in the arts, for calico printing or for stiffening clothes, is obtained from wheat grains and potatoes. A finer quality, for medicinal purposes, is obtained, as *arrow-root*, from the root of the *Maranta Arundinacea*. *SAGO* and *TAPIOCA* are other forms of nearly pure starch.

Starch is an important element of animal food, as it furnishes not only the elements of an increase of mass, but the materials also of maintaining respiration and supplying the animal heat.

Prep. The principal sources of starch are wheat, potatoes, and rice. The first contains from 56 to 76 pr. ct., the second from 15 to 30 pr. ct., and the third from 80 to 85 pr. ct. It is prepared from the grains of the cereals by soaking and crushing and fermenting them. The acetous fermentation thus produced at the expense of the sugar present, promotes the solution of the gluten, so that, by washing the crushed grains in baskets with running water, the starch is carried through the meshes as a milky liquid, which must be run upon hair sieves into clean vats. In a short time the starch subsides, and the supernatant liquor is then to be decanted, and the upper stratum of *slimes* also removed. After repeated washings with fresh waters, the starch is to be well stirred, and the milky liquor again strained upon hair sieves of greater fineness than those first used. After repose, the water and *slimes* are to be separated as before, the starch drained in linen bags, and dried by exposure to the sun or in a warm room. For full particulars as to the manufacture of the different kinds, see "*Parnell's Applied Chemistry*," ii. pp. 97—159.

Prop. Formula $C_{12}H_{10}O_{10} + 2HO$. When heated in vacuo at 250° — 260° , it is changed into $C_{12}H_9O_9$, HO ; and by combination with oxides it loses its remaining equiv. of water. The composition of its lead salt is $2PbO$, $C_{12}H_9O_9$ (*Payen*). According to Jacquelin, starch always contains a small portion of nitrogen; and Payen (*Comptes Rendus*, xxiii. 487) has shown the pre-existence of an essential oil. By exposure to moist air, water is reabsorbed. Whatever its origin, starch is in the form of brilliant white, round, pulverulent granules, varying in size, from $\frac{1}{100}$ to $\frac{1}{10,000}$ ths of an inch in diameter, with the plant whence derived. Each grain consists of several concentric layers, decreasing in thickness and hardness interiorly. Is insoluble in alcohol and ether, and also in cold water, but at 150° forms with the latter a thick solution, which gelatinizes on cooling. Below this temperature, say at 140° , the starch separates into two portions without solution of either; or .003 to .004 is left unacted upon, while the residue forms a jelly. This behavior has given rise to the idea of distinctive portions, which have been termed *amidine* and *amidin*: but there is no difference, the residual portion being the more refractory, harder layer of the grains, soluble by boiling in water. The action of boiling water increases the volume of the starch thirty-fold. When the heat is raised to 395° — 430° , a change of properties ensues, and it is converted into *Dextrin*. If heated with five parts of water in a digester at 320° , according to Jacquelin, a gum-like product, similar in properties to dextrin, results; but if the temperature is raised to 356° , much sugar is formed, thus proving the catalytic action of the water. Heating hydrated starch in a closed tube to 212° — 266° , merely converts it into a paste,—to 305° , forms a transparent solution, which on cooling deposits minute granules, soluble in water at 158° to 212° , but not altered in properties from the original starch. Continued ebullition of starch paste for several days, converts it into a bitter matter and undetermined gummy principles.

The most characteristic test for the presence of starch is iodine, which imparts a deep violet color when pure and moist. The iodine must not be used in excess. The color disappears when the paste is heated, but returns again on cooling. Starch solution is precipitated by alcohol, subacetate of lead, lime, and tannin.

When swelled by moisture, granules of starch are possessed of double refraction, in consequence of the pressure exerted by the teguments upon their contents, and present a very beautiful appearance when viewed in a microscope by polarized light, for which purpose they may be put up either in Canada balsam or water. When the planes of polarization of the polarizer and analyzer are at right angles to each other, a distinct black cross is perceived (such as that exhibited in similar circumstances by doubly refracting crystals), the centre of which is at the hilum of the granule. The remainder of the granule is white, but the field or ground is black or gray. On rotating either the analyzer or polarizer 90° , the black cross is replaced by a white one, the other parts of the granule becoming dark; the field is then white.

If a thin plate of mica or selenite is placed anywhere between the eye and the reflector of the microscope, the edges of the cross and the intervening spaces become most beautifully colored, and the field of view also assumes a tint dependent on the thickness of the mica or selenite. The adjoining spaces on either side of the cross exhibit complementary colors, which change on revolving the analyzing plate, and become complementary at every quarter of a revolution. All the varieties of starch present this appearance, but not with equal distinctness, partly on account of their unequal state of distension. It is more evident in *tous les mois*, potato starch, and Indian corn starch, than in wheat starch, barley starch, and some other kinds. (*Parnell*, vol. ii. 105, 106.)

Action of Acids. Starch is dissolved by dilute acids, excepting acetic, and by prolonged ebullition converted first into dextrin, and ultimately into grape sugar.

Strong nitric acid converts it into oxalic acid and *Xyloidin*. Concentrated sulphuric acid, according to Blondeau, when rubbed up with starch, yields a gummy mass, which liquifies and forms soluble compounds with lead, lime, or baryta. The formula of the lead salt is $C_{36}H_{36}O_{36} \cdot 2SO_3 + PbO + 2HO$; if the contact has been prolonged for 36 hours, $C_{24}H_{24}O_{24} \cdot 2SO_3 \cdot PbO, 2HO$. If the acid is diluted with 2 pts. of water, the starch is carbonized, and formic acid generated.

Action of Alkalies. Ammonia alone is without action upon starch grains. A ley containing 2 pr. ct. of soda swells the grains to 60—70 times their original bulk. According to Gottlieb (*Ann. der Chem. und Pharm.* lii. 121), fused hydrate of potassa transforms it into formic, acetic, and metacetic acids. When brayed with strong potassa ley, it unites and forms a transparent, gelatinous compound, soluble in water and in alcohol, from which starch is precipitated by acids.

Action of DIASTASE. This substance produces a series of reactions. At first it only causes liquefaction and deposition of minute granules at 140° — 160° , as when heated in a digester. Thus far the starch continues to be blued by iodine, but when by further reaction of the diastase, it is converted into dextrin, the tint passes gradually into violet and purple, and ultimately disappears, when the dextrin becomes sugar.

There are other varieties of starch, with slight differences in physical properties. The principal ones are,—*Cassava*, from the tuberous root of the *Jatropha manihot*; *Salep*, from the different species of *Orchis*; and *Tous les mois*, from the *Canna coccinea* (?). They are doubtless “mere structural modifications of the same chemical substance.” *Inulin*, from the helenium and dahlia, and *Lichenin*, from the lichens, are so analogous to starch, in many respects, as to be considered varieties, but they differ in certain chemical characteristics, and even in composition.

Gobley (*Journ. de Pharm.* 1844) has given the following method of distinguishing between the various kinds of starch by means of iodine:—

The author places the starch in watch-glasses under a bell-glass containing iodine, and leaves

them exposed there for four-and-twenty hours, when the granules acquire the following colorings:—

Wheat starch.....	Violet.
Potato starch.....	Dove-gray.
Genuine arrow-root	Bright chocolate color.
Arrow-root, with $\frac{1}{4}$ wheat starch.....	Grayish lilac.
Manufactured arrow-root	Dove-gray.
Genuine tapioca, entire.....	All the granules yellowish.
The same, pulverized..	Chamois color.
Pulverized tapioca, mixed with $\frac{1}{4}$ wheat starch.....	Violet.
Spurious tapioca, entire.....	Some granules of a violet-gray, others yellowish.
The same, pulverized..	Chamois color.
The same, with $\frac{1}{4}$ wheat starch.....	Violet.
White sago, entire	Some granules of a violet-gray, others yellowish.
The same, pulverized..	Chamois color.
The same, with $\frac{1}{4}$ wheat starch.....	Violet.
Spurious sago, entire, {	Some granules violet-gray, the others yellowish.
The same, pulverized..	Chamois.
The same, with $\frac{1}{4}$ wheat starch.....	Violet.
Dextrin	No coloring.

From the above it will be seen that wheat and potato starch acquire, under the influence of iodine vapor, a widely different coloring; that arrow-root, which when pure assumes a light chocolate color, becomes of a lilac-gray when mixed with $\frac{1}{4}$ wheat starch; and that spurious arrow-root assumes a dove-gray color, that is to say, the same coloring as the potato starch from which it had been prepared; that the tapiocas and sagos, entire, genuine, or spurious, acquire the same yellowish tint; that the powders, genuine and spurious, all acquire a chamois color.

Thus it is possible, by means of iodine vapor, to distinguish between wheat and potato starch, genuine arrow-root from spurious, or when mixed with wheat starch. It is also possible to determine whether the tapioca powders, genuine and spurious, have been replaced by corn or potato starch, or have been mixed with them; but it will be impossible to decide whether manufactured tapioca and sago powders have been substituted for genuine.

The coloring of the starch granules is owing to the property which these bodies possess, of absorbing the vapor of iodine and water. Experiment shows that these granules are not colored by iodine, unless moist. When they have been dried at 212° they absorb iodine, it is true, but only become colored on recombining with water. (*Chem. Gaz.* ii. 238, 239.)

Another mode of distinguishing between the different varieties of starch, is by their microscopic characters, and we therefore annex a synopsis, taken from *Parnell's Applied Chemistry*, vol. ii. pp. 144—146:—

Starch from potatoes. With the exception of *tous les mois*, the granules of potato starch are larger than those of any other kind. The elliptical rings are unusually distinct in potato starch. The common size of the granules is from $\frac{1}{300}$ to $\frac{1}{200}$ of an inch in diameter. The cross and supplementary colors by polarized light are very distinct.

Sago. The granules of sago meal or pulverulent sago, are somewhat rounder than those of most other kinds of starch. Their size is pretty uniform, and about the $\frac{1}{400}$ of an inch in diameter. Most of the granules of pearl sago are ruptured, but those of brown sago are perfect. The cross by polarized light is very distinct.

Starch of oats. That which appears to be a large granule of oat starch, when examined by a power of one hundred diameters, proves with a higher power to be a glutinous cell, to which small granules of starch are attached, the diameter of which is about $\frac{1}{500}$ of an inch.

Starch of the kidney bean. The granules are ovoid, and have a point on one side. The diameter of the largest is about $\frac{1}{400}$ of an inch.

Wheat starch. The granules rarely exceed $\frac{1}{300}$ of an inch in diameter; they are spherical, and when prepared from flour, are often accompanied by the teguments of broken granules. Wheat starch does not exhibit the cross by polarized light as distinctly as most other starches.

Starch of barley. The granules are about the same size as those of wheat starch, and almost circular. The cross by polarized light is not very distinct.

Starch of rye. The largest granules of this starch have a diameter of $\frac{1}{500}$ of an inch. They are flattened, and generally marked on one of their faces by a small black cross, or by three black rays proceeding from the hilum of the granule. (*Raspail.*)

Starch from the bean. The usual size of the granules is $\frac{1}{500}$ of an inch in diameter. They are ovoid or reniform.

Starch from green peas. The granules have the same form as those of potato starch, and a diameter of about $\frac{1}{500}$ of an inch. (*Raspail.*)

Arrow-root. The granules of arrow-root are not so spherical as most other starches, being generally flattened at one end. The spherical lines are not so well defined as in *tous les mois* and potato starch, but the cross by polarized light is very distinct. The diameter of the largest globules is about $\frac{1}{500}$ of an inch.

Starch of the horse-chestnut. The form of the granules is very irregular. Their longest diameter is about $\frac{1}{400}$ of an inch, but varies considerably according to the size and age of the nut.

Starch of the tapioca plant or tapioca meal. The granules are spherical, equal in size, and about $\frac{1}{500}$ of an inch in diameter. The hilum is very distinct, as well as the cross and colors, by polarized light.

Russian semolina. A few of the granules are ruptured. The perfect granules are spherical, and about $\frac{1}{800}$ of an inch in diameter. The cross by polarized light is not shown distinctly by this variety of starch.

Indian corn starch. The granules are almost

perfectly spherical, and the diameter of the largest does not exceed $\frac{1}{800}$ of an inch. The cross with polarized light is very clear.

Starch of the orchis tribe. Before the root is converted into salep by ebullition, the granules appear perfectly spherical, and the diameter of the largest is no more than $\frac{1}{2500}$ of an inch. (*Raspail.*)

Starch of the millet. The granules of this starch are the smallest Raspail has observed, being only $\frac{1}{15000}$ of an inch in diameter.

STAUROLITE. *Min.* Staurotide, Grenatite. Cryst. Right rhombic; frequently compounded in two directions, making crosses of the two forms + and X, whence its name from Greek, *Cross-stone*. H. = 7-7.5. G. = 3.527-3.741. Dark brown to black; vitreous, resinous; translucent, opaque; fracture conchoidal; streak whitish. In fine powder fusible on the edges to a black slag; difficultly soluble in borax and mic. salt, showing iron, and becoming opalescent in the latter; effervesces with soda to a yellow slag; not decomposed by muriatic, and but partially by sulphuric acid. The formula varies from $2\text{R}_2\text{O}_3, \text{SiO}_3$ to $5\text{R}_2\text{O}_3, 4\text{SiO}_3$, in which $\text{R}_2\text{O}_3 = \text{Al}_2\text{O}_3$ and Fe_2O_3 . Fine, single crystals in kyanite, occur on St. Gotthardt and Greiner. It is usually in mica-slate, and in considerable abundance in many localities in the U. States; among others on the Schnylkill and Wissahickon, near Philadelphia; and very distinct brown crosses from Etowah, Cass Co., Georgia. It is allied to kyanite and andalusite.

STEARIN. *Chem. Tech.* Syn. Stearate of the oxide of Glyceryl. Exists naturally in FATS, as their more solid constituent.

Prop. Pure stearin is prepared by adding 10 pts. of ether to 1 pt. of liquid mutton suet, pressing the crystals, which form after repose, and washing them with cold ether. On a large scale it may be made from either lard or suet, by the use of spirits of turpentine, and for the details of this economical mode, see "*Morfit's Applied Chemistry.*"

Prop. Viewed as an acid stearate of glycerin, its formula is $\text{C}_{66}\text{H}_{164}\text{O}_4, \text{C}_{66}\text{H}_{166}\text{O}_5 + 2\text{HO}, \text{C}_{68}\text{H}_{166}\text{O}_5 = \text{C}_{142}\text{H}_{314}\text{O}_{16}$, in which the glycerin is taken, according to the analysis of Pelouze, less 2 eqs. water, and the acid, according to the analysis of Redtenbacher. Regarded as a neutral stearate of glycerin (halved), its formula is $\text{C}_3\text{H}_3\text{O}_2, \text{C}_{66}\text{H}_{166}\text{O}_5, \text{HO} = \text{C}_{71}\text{H}_{170}\text{O}_8$. But if, with Berzelius, we adopt oxide of lipyl as the base, the formula becomes $\text{C}_3\text{H}_2\text{O}, \text{C}_{68}\text{H}_{166}\text{O}_5, 2\text{HO}$. Which of these bases is the correct one, or, indeed, whether the above or Chevreul's analysis of stearic acid, $\text{C}_{70}\text{H}_{167}\text{O}_5$, be correct, cannot be satisfactorily determined; but Redtenbacher's formula for the acid is most probably correct. It is certain that glycerin, as analyzed by Pelouze, does not enter into the composition of stearin nor any of the fats, for in combining it loses 2 eqs. water. Moreover, there are some fats which, upon a comparison of their analyses with those of their acids, seem to indicate that they contain only oxide of lipyl as their base. Stearin crystallizes in pearly scales, but, as obtained on a large scale, it retains more or less olein, and is in hard, amorphous masses. That made from tallow is white and marble-like, while

lard-stearin is translucent, and very similar to wax in appearance and physical properties. When pure it melts at 140° to 144° , and congeals into a non-crystalline mass. Is insoluble in water; dissolves in 7 or 8 pts. boiling alcohol, and drops on cooling in white flocculæ. Ether takes it up readily, but when cold does not retain but $\frac{2}{3}$. Sulphuric acid separates the stearic acid, and unites with the glycerin, forming sulpho-glyceric acid. In the cold, stearin forms compounds with the alkalies from which it may be separated unaltered, but by saponification it is decomposed and resolved into glycerin and stearate.

Stearic acid. Syn. Hypomargarylic. Is bi-basic (?). Formula $C_{68}H_{66}O_5$ (anhydrous), and $C_{68}H_{66}O_5 + 2HO$ (hydrated). (Redtenbacher.) Is best prepared by decomposing the stearate of lime with sulphuric acid, decanting the supernatant oily liquid, and when cold dissolving it in alcohol and crystallizing. It may be further purified by recrystallization from alcohol. On a large scale, in the material of "Star," "Adamantine," and "Stearin" candles, it is prepared by making a lime-soap of tallow or lard, decomposing it with dilute acid, granulating the separated fat, fusing it to expel the liquid or oleic acid, and steaming to whiten and purify it. All the minutiae for the manufacture of these candles are recorded in Morfit's "Applied Chemistry."

Prop. Stearic acid crystallizes from alcohol in brilliant, pearly needles, which are greasy to the touch, soluble in ether, and insoluble in water. Fuses at 167° , and solidifies at 158° into a crystalline mass, and burns with a clear flame, like wax. Spec. grav. of the solid stearin, 1.01, of the liquid 0.854. If heated in close vessels, stearic acid may be distilled unaltered, but the presence of air modifies it into new products, among which are margaric acid, margarine, and a liquid carbohydrate. By the distillation of 4 pts. of acid with one of lime, there are generated an oily matter soluble in ether, a crystalline body, *Stearone* (Bussy), of the formula $C_{59}H_{45}O$, and melting at 187° , and a matter fusible at $179-6^{\circ}$, of the composition $C_{46}H_{45}O$. (Redtenbacher.)

Oxidizing agents transform stearic into margaric acid, and by prolonged action ultimately into the products of the latter acid. Sulphuric is without any appreciable action. Anhydrous phosphoric acid removes 2 eqs. of water, and converts it into—

Anhydrostearole, $C_{68}H_{66}O_5$ (Erdmann). A brilliant yellow solid, of less spec. gravity than water. Melts at 130° to 140° , is very soluble in ether, but only slightly in alcohol. Potassa is without action, and nitric acid converts it into a waxy matter.

Stearic acid forms two series of salts, in one of which but a single equivalent of water is displaced by the bases, and in the other both.

Stearate of Potassa. $2KO, C_{68}H_{66}O_5$. This, the neutral salt, crystallizes in brilliant white scales and needles of an alkaline taste, unalterable in the air, and fusible at 212° . Is readily soluble in boiling, but only slightly in cold alcohol, and insoluble in ether. If to its solution in boiling water cold water is added, the pearly bi-stearate is precipitated, and caustic potassa remains in solution.

Bi-stearate of Potassa. $KO, \overline{St} + HO$. Crystallizes in pearly scales from an alcoholic solution. It is insoluble in cold water, but by boiling 1 pt. with 1000 of water, an insoluble quadristearate, $C_{68}H_{66}O_5, 2KO + 3(C_{68}H_{66}O_5, 2HO)$, is formed. The filtered liquor then drops, upon cooling and repose, bi-stearate of potassa, while it retains in solution an alkaline stearate.

The corresponding soda salts are very analogous, though less soluble in water, and less easily decomposed.

The stearates of lime, baryta, and strontia are formed by double decomposition from the neutral salt of potassa. They are white, solid, insoluble, and of the formula $2RO, C_{68}H_{66}O_5$.

There are three lead salts: the *neutral*, $2PbO, \overline{St}$; the *basic*, $4PbO, \overline{St}$; and the *acid*, which like the second is a transparent plaster, fusible at 212° .

Stearates of the Oxide of Ethyl. The neutral ether is $2AeO, \overline{St}$, an oily solid. The bi-salt, $AeO, HO, \overline{St}$, is wax-like. It melts between 80° and 90° , and decomposes at 329° , is insoluble in water, soluble in ether and hot alcohol, from which latter it drops, on cooling, in white, silky needles. (Redtenbacher.)

STEAROPHANIC ACID. $C_{35}H_{34}O_3, HO$. Obtained by Francis from the *Coculus Indicus*. A solid, crystallizable fat, fusing at 154° .

STEAROPTEN. *Chem.* The crystallizable portion of **ESSENTIAL OILS**. In some instances this solid constituent is isomeric with the oil, and in others is an oxide. When formed under the influence of water, it is a hydrate.

STEATITE. *Min.* Soapstone, Speckstone. Massive and granular. $H. = 1-1.5. G. = 2.5-2.8$. Greenish, yellowish, lead-gray, white; lustre pearly; translucent, subtranslucent; sectile, with white streak and soapy feel. Yields water in a tube; scarcely fuses on the edges to a white enamel; gives a red tint with cobalt solution; decomposed by muriatic acid. The varying formulas $6MgO, 5SiO_3 + 4HO$ and $Al_2O_3, 2SiO_3 + 6(MgO, HO)$, &c. show a variable composition from the presence of different quantities of water, and other foreign ingredients. It may be like talc, a simple silicate of magnesia, MgO, SiO_3 , with a varying adulteration of MgO, HO , and a replacement of part of the MgO by FeO . Steatite occurs in large beds in different parts of the U. States. A fine quarry, from which large slabs are cut, is on the Schuylkill, about 8 miles from Philadelphia. See **TALC**.

STEINHEILITE. See **CORDERITE**.

STEINMANNITE. *Min.* Cryst. Regular, cubic, with the same cleavage. $H. = 2.5. G. = 6.83$. Lead-gray; metallic. Gives with the blowpipe sulphurous acid, oxide of antimony, lead, and silver. Allied to sulphantimonates of lead. From Przibram, Bohemia. See **ANTIMONIAL ORES**.

STELLITE. *Min.* Radiated acicular crystals and fibres. $H. = 3.25. G. = 2.612$. White, silky, shining, translucent. Fuses with effervescence to a white enamel; gelatinizes with muriatic acid. Thomson's analysis of stellite, from Kilsyth, Scotland, leads to the formula $9(CaO, SiO_3) + Al_2O_3, 3SiO_3 + 6(MgO, HO)$; in the last member, $\frac{1}{2}$ of the

MgO is replaced by CaO. Beck's and Hayes' analyses of stellite, from Bergen Hill, N. Jersey, give a different formula, and the latter finds 6.75 pr. ct. soda with but a trace of magnesia.

STERNBERGITE. *Min.* Cryst. Right rhombic, with perfect basal cleavage. $H. = 1-1.5$. $G. = 4.215$. Pinchbeck-brown; metallic; opaque; very sectile, with black streak; leaving traces on paper; thin laminae flexible. It fuses on coal, evolving sulphurous acid, and leaving a magnetic globule, coated with silver; with borax it yields a silver globule and an iron-colored slag. Soluble in aqua regia with separation of sulphur and chloride of silver. Form. $AgS + 2Fe_2S_3$. From Joachimsthal, Bohemia, with ruby silver.

STILBITE. *Min.* Radiated, foliated zeolite, Spherostilbite, Hypostilbite, Desmin, Strahl-zeolith. Cryst. Right rhombic, with 8-hedron and end-planes of all axes; cleaves perfectly parallel to one lateral axis; also columnar, fibrous, foliated. $H. = 3.5-4$. $G. = 2.133-2.203$. White, sometimes tinted yellow, brownish, red; lustre of cleavage face pearly; subtransparent, translucent; brittle, with uneven fracture and white streak. It behaves like all zeolites before the blowpipe, and is perfectly decomposed by muriatic acid, its silica separating in powder. Form. $CaO, SiO_3 + Al_2O_3, 3SiO_3 + 6HO$, a portion of the lime being at times replaced by soda. It occurs most frequently in trapezoid rocks, and is met with in granitic rocks. See **AEDOLFORSITE**. **EPISTILBITE**.

STILPNOMELAN. *Min.* A black, foliated mineral, with green streak, a hydrated silicate of alumina, and protoxide of iron; from Olurgund, in Austrian Silesia. Berzelius regards it as a mixture.

STILPNOSIDERITE. See **BROWN HEMATITE**.

STINKSTONE. *Min.* Fetid, calcareous spar.

STORAX. The balsamic juice of the *Styrax officinale* and *Liquidambar styraciflua*. It consists, according to Simonde, of volatile oil, resin, styracin, and cinnamic acid. The resin is a compound of two, one hard, the other soft, and analogous to cinnamon.

Styracin. $C_{24}H_{11}O_2$. Crystallizes in white needles, which are neutral, fusible at 122° , insoluble in water, soluble in 3 pts. of boiling, and 22 of cold alcohol, and in 3 pts. of ether. Nitric acid generates, among other products, prussic acid and hydrate of benzoyl. Distilled with hydrate of lime, it yields an oil isomeric with benzin, but of different properties. Potassa converts it into styracone, while the alkali combines with cinnamic acid. (*Simon.*)

Styracone is a heavy, oily liquid, containing oxygen, and boiling at 428° .

By distillation with water, storax yields—

Styrole. C_8H_8 (*Hoffman and Blyth*). A colorless oil, refracting light strongly. When heated in a closed vessel to 400° , it solidifies into *Meta-styrole*, isomeric with it, and also with *draconyl*. By stronger heat it is reconverted into styrole. According to Hempel, styrole is a derivative of cinnamic acid.

STRAMONIN. *Chem.* Found by Trommsdorff accompanying **DATURIN**, in the *Datura Stramonium*. Crystallizes in white needles, which are inodorous, tasteless, and soluble in

ether. It dissolves also to a slight extent in alcohol, but is insoluble in water. Heated to 302° , it melts and sublimes. Sulphuric acid reddens it; nitric acid is without reaction.

STROGANOVITE. *Min.* It is **CANCERINITE**, with a large amount of lime replacing the soda.

STROMEYERITE. *Min.* Cupreous sulphuret of silver; Silberkupferglanz. Massive. $H. = 3-4$. $G. = 4.258$. Steel-gray, metallic, sectile with shining streak. Fuses readily to a gray, metallic, half-malleable globule, which shows copper with the fluxes, and gives silver by cupellation; soluble in nitric acid with separation of sulphur. Form. $Cu_2S + AgS$. From Schlangenberg, near Colivan, in Siberia.

STRONTIANITE. *Min.* Carbonate of strontian. Cryst. Right rhombic, with lateral cleavage nearly perfect; also fibrous, granular. $H. = 3.5-4$. $G. = 3.6-3.713$. Green, white, gray, yellow, brown, usually light colors; vitreous; transparent, translucent; brittle with white streak. It puffs by heat, fuses on the edges, illuminates powerfully, and gives a reddish color to the reducing flame; soluble with effervescence in the fluxes, and fuses with as much soda to a clear glass, which becomes milky on cooling; soluble in acids with effervescence. It is carbonate of strontia, SrO, CO_2 , with varying quantities of carbonate of lime. From Strontian, Scotland; Saxony; Schoharie and Warwick, N. York.

STRONTIUM. *Chem.* The earth was discovered 1790—1793, the metal by H. Davy, 1808. It exists in less abundance than baryta, as sulphate and carbonate (celestine and strontianite), in a few other minerals, and in minute quantity in many mineral waters.

Strontium, its Oxide and Sulphuret.

1. *Strontium.* *Prep.* The same as **BARIUM**, which it resembles in appearance, but is less fusible, decomposes water, evolving hydrogen. Sym. Sr. Eq. = 43.84 ($43.67 H. = 1, 545.93$. $O. = 100$, *Berz.*)

2. *Strontia.* Oxide of strontium, SrO . The dry earth is prepared like baryta, and also by powerful ignition of the hydrate; it is caustic, infusible. The *hydrate*, made by moistening the dry earth, is a white powder, SrO, HO ; and from a strong hot solution, crystals separate, of the form. $SrO, HO + 8HO$, which are soluble in 50 pts. cold, 2.4 boiling water, and lose 8 HO by 212° or above. Hyperoxide of strontia, made by bringing together binoxide of hydrogen, water, and hydrate of strontia, forms pearly scales.

Salts. It is a feeble base than baryta; its salts are colorless, not poisonous, generally soluble in acid water, except the sulphate; give white precipitates with carbonate, phosphate, arseniate, oxalate, tartrate and sulphate of alkali, which are soluble in muriatic acid, except the sulphate; the limits of the sulphate test are, 1 pt. nitrate of strontia to 5000 water, immediate cloudiness; 1 to 20,000, slight cloudiness after some minutes. The best test, combined with that of sulphuric acid in dilute solutions, is the carmine color imparted to flame, especially when held on the edge of a blue flame.

Sulphuret of Str., SrS . Prepared from the sulphate by ignition with charcoal, is white.

STRONTIUM.

STRYCHNIN.

Dissolved in water, it separates into sulphurate of sulphuret of strontium and hydrate of strontia, which last crystallizes. The sulphurate is made by extracting the sulphuret by a little water, or by passing sulphohydrogen through water containing the sulphuret or hydrate suspended in it. It crystallizes by evaporation in vacuo.

HALOID SALTS.

1. *Chloride of Str.* Obtained like the salt of barium; crystallizes with the form. $\text{SrCl} + 6\text{HO}$; is deliquescent in moist air, soluble in $\frac{3}{4}$ pts. cold, and in every proportion in hot water, in 24 pts. cold, and 19 boiling absolute alcohol; it loses water by heat, fuses, and loses chlorine; imparts the most brilliant red color to alcohol flame. It absorbs, when dry, 4 eqs. ammonia gas.

2. *Bromide of Str.* Crystallizes with the form. $\text{SrBr} + 6\text{HO}$; loses water by heat, and fuses without decomposition.

3. *Iodide of Str.* Is very soluble in water, and fusible with decomposition.

4. *Fluoride of Str.* Prepared like that of barium; is a white powder, little soluble in water and fluohydric acid.

OXYSALTS.

1. *Sulphate of Str.* (See CELESTINE.) SrO, SO_3 . Is formed by precipitation as a white powder, fusible at a high heat, soluble in 3600 pts. water at 60° , less in water containing sulphate of soda, still less in that containing sulphuric acid, slowly but wholly soluble in a solution of common salt, reprecipitable by sulphuric acid. The *sulphite*, SrO, SO_2 , is a white, almost insoluble powder. *Hyposulphate* is permanent, crystallizable, soluble in $4\frac{1}{2}$ pts. water at 61° , in $1\frac{1}{2}$ boiling water, insoluble in alcohol; form. $\text{SrO}, \text{S}_2\text{O}_5 + 4\text{HO}$. *Hyposulphite* or dithionite forms by exposure of a solution of sulphuret to the air, or by passing sulphurous acid through it until it becomes colorless. By adding alcohol, or by evaporation, it crystallizes; permanent in air, soluble in 4 pts. cold, in $1\frac{3}{4}$ pts. boiling water; form. $\text{SrO}, \text{S}_2\text{O}_2 + 5\text{HO}$.

2. *Nitrate of Str.* Made from the sulphuret or carbonate, crystallizes from hot, concentrated solutions in anhydrous crystals, from cold, dilute solutions with the form. $\text{SrO}, \text{NO}_5 + 5\text{HO}$, and efflorescent; soluble in 5 pts. cold, in $\frac{1}{2}$ pt. boiling water. The dry nitrate forms crystals, permanent in air.

3. *Phosphate of Str.*, $2\text{SrO}, \text{PO}_5$, is a white powder, insoluble in water, soluble in acids and ammoniacal salts, reprecipitable by ammonia, not decomposed by potassa or soda, fusible to a white enamel. *Phosphite*, $2\text{SrO}, \text{PO}_3$. Is crystallizable, and decomposes by water into an insoluble and soluble salt. The *Hypophosphite*, SrO, PO , formed by boiling phosphorus and strontia, is soluble and crystallizable.

5. *Chlorate of Str.* Obtained like that of baryta, is crystallizable, deliquescent in air, and rather soluble in alcohol. The *perchlorate* is still more deliquescent, but crystallizable. The *chlorite* is crystallizable and deliquescent.

4. *Bromate of Str.* Formed direct, crystallizes with the form. $\text{SrO}, \text{BrO}_5 + \text{HO}$, soluble in 3 pts. cold water.

6. *Iodate of Str.* Is formed by dissolving

iodine in strontia water, or precipitating chloride of strontium by iodate of soda. If the precipitation take place from a hot solution, the salt is a white powder, of the form. $\text{SrO}, \text{IO}_5 + \text{HO}$; if from a cold solution, the crystals have the form. $\text{SrO}, \text{IO}_5 + 6\text{HO}$; the crystals are soluble in 342 pts. water at 59° , in 110 pts. boiling water. A basic *periodate* is obtained by igniting the iodate.

7. *Carbonate of Str.* (See STRONTIANITE.) Is obtained by precipitation as a white powder, soluble in carbonic acid water and in 1536 pts. water, and crystallizable from the former; heated in a current of steam, it becomes caustic. *Oxalate* is white, soluble in 1920 pts. boiling water.

8. *Biborate of Str.*, $\text{SrO}, 2\text{BO}_3$. Is almost insoluble in cold, soluble in 130 pts. boiling water; it has alkaline reaction, and is fusible. *Sexborate* is also rather insoluble. Silicates have not been examined, although they can be formed.

STRUVITE. *Min.* Crystals of ammoniaphosphate of magnesia, $2\text{MgO}, \text{PO}_5 + \text{NH}_3 + 13\text{HO}$, from the soil near Nicolai-Church in Hamburg, formed by decomposition of animal matter.

STRYCHNIN. *Pharm. Chem.* An alkaloid found by Pelletier and Caventou, accompanying BRUCIN and Igasuric acid, in the seeds of the *Strychnos NUX VOMICA*. It exists also in the seeds of the *S. ignatia*, *innocua*, *spinosa*, and *petatorum*; in the wood of the *S. colubrina*, in the root bark of the *S. tieute*, and in the *Woorary* or *Ourary*, which is the juice of the *S. toxifera*. It is supposed to be likewise present in false Angustura bark.

Prep. The process for making strychnia is exactly the same as for QUININ, until the residue after the distillation is taken from the still; then, instead of neutralizing with sulphuric acid, the concentrated liquid is allowed to crystallize, the solid mass is then pressed and treated repeatedly with dilute alcohol, until the removal of all extractive matter and brucin. This being done, the cleansed strychnin is to be diffused in hot water, neutralized with sulphuric acid, and crystallized repeatedly from alcohol, until white, when it may, while in solution as sulphate, be precipitated in fine granules by aqua ammonia. Resolution in, and crystallization from alcohol, yields fine crystals.

Lebourdais separates the strychnin from an aqueous decoction of nux vomica, in the same manner as given for QUININ. This mode of extracting the alkaloids gives rise to the inference that the use of bone-black, as an agent for decolorizing their solutions, occasions the loss of a portion precipitated by, or combining with it. With a view to the determination of this opinion, a series of experiments are in contemplation, and will be executed upon the refuse black obtained at a laboratory, from the crystallizations of morphin, quinin, and strychnin. (C. M.)

Prop. $\text{C}_{44}\text{H}_{23}\text{N}_2\text{O}_4$; $\text{C}_{44}\text{H}_{24}\text{N}_2\text{O}_4$ (Dollfus). Dissolves in boiling alcohol of 850 , and drops, on cooling, in colorless, transparent, octahedral prisms. Is insoluble in ether and absolute alcohol, and only to a very slight extent (1 in 2500) in hot water. The solution as well as

the vapor are intensely bitter. It is neither fusible nor volatile, but decomposes at 600° . Pure strychnin is not reddened by nitric acid, and this test is used to detect brucin, not unfrequently present, and which is *immediately* colored red by it. A very delicate and characteristic test for strychnin in toxicological cases, is that of E. Marchand, verified by the experiments of Dr. Erdmann upon $\frac{1}{2}$ milligramme of strychnin in 12 grms. of milk. The method is to triturate the strychnin with a small quantity of peroxide of lead, and to let fall upon the mixture a drop of sulphuric acid containing 1 pr. ct. of nitric acid. A magnificent blue color is instantaneously developed, and passes quickly to violet, then gradually to red, and ultimately, after some hours, to a canary-yellow. (*Journ. de Pharm.* 1848, and *Chem. Gaz.* i. 629.)

Strychnin is highly poisonous, and Duclos (*Chem. Gaz.* ii. 108) has recommended the application of the *negative* electricity as a remedy.

Strychnic acid. Prepared by boiling together a paste of 3 pts. strychnin and 1 pt. of chlorate of potassa (moistened and warmed with a little water and a few drops of sulphuric acid) in 10 pts. of distilled water (*Rousseau*). The solution, on cooling, drops strychnia or sulphate, and must then be filtered. The filtrate, by evaporation, yields crystals of strychnic acid, in fine white needles. Is readily soluble in water, but with difficulty in alcohol, and forms crystallizable salts with the bases. (*Journ. de Chim. Med.* 1844.)

Sulphate, $\overset{+}{\text{St}}, \text{SO}_3 + 7 \text{HO}$. Crystallizes in colorless, rectangular prisms, or in cubes, which become opaque by exposure to air. The acid sulphate crystallizes in needles. Soluble in 10 pts. of cold water.

Nitraté, $\overset{+}{\text{St}}, \text{NO}_5 + \text{HO}$. In pearly needles, more soluble in hot than cold water, slightly soluble in alcohol, and insoluble in ether. There is also an acid nitrate.

Muriate. $\overset{+}{\text{St}}, \text{HCl} + 2 \text{HO}$.

Ferrocyanide. $(2 \overset{+}{\text{St}}, \text{HCy} + \text{FeCy}) + 8 \text{HO}$ (*Brandis*). Long, rectangular prisms, straw-yellow, sparingly soluble in cold water and alcohol, and more so in hot.

Ferriacyanide. $(3 \overset{+}{\text{St}}, \text{HCy} + \text{Fe}_2\text{Cy}_3) + 12 \text{HO}$ (*Brandis*). Golden-yellow prisms, very sparingly soluble.

Muriate of Strychnin and Cyanide of Mercury. $\overset{+}{\text{St}}, \text{HCy} + 4 \text{HgCy}$ (*Brandis*). Colorless, pearly prisms. (*Journ. für Prakt. Chem.* 1848.)

Sulphocyanide of Strychnia. $\overset{+}{\text{St}} + \text{C}_2\text{NS}_2\text{H}$. Crystallizes in transparent needles. (*Liebig's Annalen*, 1848.)

STUPP. One of the products obtained in the working of the bituminous mercurial ores, in Idria. A soft, black mass, mixed with globules of mercury. See IDRYL.

STYRACIN. } See STORAX.

STYROLE. }

SUB. See SUPER.

SUBERIC ACID. *Chem.* Brugnatelli first obtained it as a product of the oxidation of cork, by nitric acid, and hence its name from *Suber*, the Latin word for that substance.

Laurent and Bromeis obtained it more abundantly by the action of nitric acid upon fats.

Prep. Boil together, for some time, equal weights of stearic and nitric acids (spec. grav. 1.285), and evaporate the solution one-half. The crystals which deposit are hydrated suberic acid, which require to be washed with cold water, and purified by recrystallization.

Prop. $\text{C}_8\text{H}_6\text{O}_3$, HO. Crystallizes in white granules; fusible, if moist, at 130° , and if dry, at 238° , and sublimes at a higher heat, condensing into an oily liquid, which congeals into long needles. Is very soluble in water and boiling alcohol, and in 10 pts. of hot, or 6 pts. of cold ether.

The alkaline suberates are all soluble in water; the earthy salts are insoluble. The suberate of silver = $2 \text{AgO}, \overline{\text{Su}}$, and the neutral salt of lead has an analogous formula, but the composition of the basic salt is $3 \text{PbO}, \overline{\text{Su}}$. Suberic ether, AeOSu , is a colorless, oily fluid, of spec. grav. 1.003, which boils and distils at 500° , unaltered.

Suberone. $\text{C}_8\text{H}_7\text{O}$ (*Boussingault*). Obtained by distilling suberic acid with lime or baryta. Its high boiling point (367°) permits its separation from the accompanying products, which are more volatile. Is a colorless, fragrant liquid, which by exposure to air or action of nitric acid, absorbs oxygen, and is transformed into suberic and other acids.

SUBERONE. See SUBERIC ACID.

SUBLIMATION. The process of distilling a solid body for the purpose of separating the more volatile portion from the fixed matter. The condensed product is termed the *sublimate*. For practical details, see *Faraday's* or *Morfil's Manipulations*.

SUBSTITUTION. *Chem.* Metalepsis, Ver-tretung. The term substitution may be applied to those changes formerly included under elective affinity, as when sulphuric acid is added to a solution of nitrate of baryta, it takes all the baryta from the nitric acid, thus replacing the latter acid. But substitution is now generally applied to a series of phenomena more generally observed in organic chemistry. By it is meant the removal of one or more equivalents of any element, except carbon, from a compound body, whether organic or inorganic, and its replacement by the same number of equivalents of another element, or of a compound, which seems to act the part of an element. When an element is so removed, it may occur that nothing enters the body to replace it, in which case there is no substitution; nor is there substitution when fewer eqivs. enter than are removed. Sometimes more eqivs. of the substitute are added than of the element substituted, in which case so many of the eqivs. of the substitute enter into intimate union, and the excess of eqivs. form a combination with the new compound. Such is an outline of the theory of substitution adopted by many, but not by all chemists. The fact of substitution cannot be doubted, for acetic acid, $\text{C}_2\text{H}_4\text{O}_4$, and chloracetic acid, $\text{C}_2\text{HCl}_3\text{O}_4$, where H_3 is replaced by Cl_3 , are remarkably similar in their properties; but the expansion which the theory has received, especially at the hands of a portion of the French school, is

too great to accord with well-established views in chemistry; and much remains to be done by experiment, before the true limits of substitution can be defined.

Hydrogen, which is most frequently substituted, may be replaced by Cl, Br, I, as in chloracetic acid, just cited; olefiant gas, C_4H_4 , yields with iodine C_4H_3I , &c. In these changes, the original acid or basic character of the substance is retained. Hydrogen is substituted by a metal; thus in the salts of the acids, one of metal replaces one of hydrogen, as in acetate of lead, $C_4H_4O_4$ becomes $C_4H_3PbO_4$. It is also substituted by red oxide of nitrogen; when certain organic bodies are acted on by nitric acid, 1 eq. O of the acid removes 1 eq. H of the organic body, forming water, which is eliminated, while the remainder of the nitric acid, NO_4 , takes the place of hydrogen; thus benzole, $C_{12}H_6 + NO_5 = HO + C_{12}H_5(NO_4)$. Sulphuric acid acts similarly, one of its oxygen taking away one of hydrogen from the organic body, and adding sulphurous acid in its place; thus benzole, $C_{12}H_6 + SO_3 = HO + C_{12}H_5(SO_2)$.

The halogens may be substituted by hydrogen, by amid, NH_2 , and by sulphur. Thus, chloracetic acid is resolved by potassium-amalgam into acetate of potassa, chloride and oxide of potassium, $C_4Cl_3O_3, HO + 6K + 2HO = C_4H_3O_3, KO + 3KCl + 2KO$; chloride of benzyl, by ammonia, into benzamid and muriatic acid, $C_4H_5O_2, Cl + NH_3 = C_{14}H_5O_2, NH_2 + HCl$; chloride of ethyl, by sulphuret of potassium, $C_4H_5Cl + KS = C_4H_5S + KCl$.

So also, red oxide of nitrogen, NO_4 , is substituted by amid, NH_2 , and by nitrogen. Oxygen is replaced by amid, by nitrogen, by sulphur, and by tellurium. Sulphur is replaced by oxygen.

Many of the above examples of substitution, given by *Gmelin*, vol. iv. pp. 64—68, may be explained by previously received chemical views, without reference to the theory of substitution. See TYPE.

SUCCHINAMIDE. See SUCCHINIC ACID.

SUCCHINIC ACID. *Chem.* Exists in AMBER, in the resins of certain *Coniferæ* (*Unverdorben*), in the fresh plants of the *Lactuca*, *Virosa*, and *Sativa* (*Köhneke*), and in the decoction of *Ab-sinth* (*Zwenger*). It is also a product of the decomposition of asparagin (*Piria*), and of the oxidation of margarin, stearin, wax, and spermaceti, and this latter is its most abundant source.

Prep. By evaporating the mother liquors of suberic acid (prepared by the action of nitric acid upon margarin), and treating the crystals which form on cooling with cold ether. The succinic acid is left undissolved.

Prop. Formula $C_4H_5O_3$ (anhydrous); $C_8H_5O_7 = 2\bar{S} + HO$ (sublimed); and $C_4H_2O_3, HO = \bar{S}, HO$ (hydrated) (*Döpping*). According to Fehling, the acid is tribasic, and when hydrated, has the composition $C_8H_3O_5 + 3HO$. Crystallizes in colorless scales or prisms, of spec. grav. 1.56, which readily volatilizes without residue. Is soluble in alcohol, but very sparingly in ether. Boiling water takes up half its weight, but retains only a fifth on

cooling. Melts at 356° , and boils at 473° . The sublimed acid melts at 320° , and fuses at 468° ; the anhydrous fuses at 293° , and boils at 482° . The last is more soluble in alcohol and ether than the other two.

Succinic acid dissolves unaltered in nitric acid, and is not acted upon by chlorine. Strong sulphuric acid, under certain circumstances, produces the *sulphosuccinic acid* ($C_4H_2S_2O_9, HO$?).

Succinates. Neutral *potassa* salt, $KO, \bar{S} + 2Aq$ (*Döpping*), in deliquescent crystals, soluble in alcohol, insoluble in ether. The bisalt contains $KO, \bar{S} + HO, \bar{S} + 4Aq$, and crystallizes in six-sided prisms, which effervesce on exposure to air, and dissolve in water and alcohol.

Succinates of Ammonia. The acid salt is $NH_4O\bar{S} + HO\bar{S}$, and the neutral, $NH_4O\bar{S}$, and both are crystallizable and soluble in water and alcohol.

Succinate of Lime. $CaO, \bar{S} + 3Aq$. In acicular crystals, which dissolve with difficulty in water, and are insoluble in alcohol.

Succinate of Oxide of Ethyl. An oily liquid, of spec. grav. 1.036 as liquid, and 6.06 in vapor. It boils at 417° , and with ammonia forms a crystalline substance apparently analogous to oxamethane. (*D'Arceet*.)

For the mode of making the salts, and the composition of a large number, see *Chem. Gaz.* ii. 29, and *Ann. der Chem. und Pharm.* xlvii. p. 253, 291.

Succinone. An oily liquid, produced by the distillation of succinate of lime. Its formula has not been correctly determined.

Succinamide. $C_8H_4O_4, 2NH_2$. A crystalline solid, formed by the action of aqua ammonia upon succinic ether. Is soluble in boiling water, and insoluble in ether and absolute alcohol. By heat it is partially transformed into—

Bisuccinamide. $C_8H_4O_6, HO + NH_3, HO$. In volatile crystals. Is also formed by heating anhydrous succinic acid in dry ammonia.

SUCCHININ. See SUCCHINIC ACID.

SUCCHISTERENE. *Chem.* A white, solid product of the distillation of AMBER, probably identical with IDRIALIN.

SUETS. See FATS.

SUGAR. *Chem. Tech. Syn. Fr. Sucre. Ger. Zucker.* A sweet-tasted principle of many vegetable juices. As an aliment it is nutritious when combined with nitrogenous food, but eaten alone, it may be viewed only as fuel for generating animal heat, and thus serving simply as a supporter of respiration. There are strictly but two kinds of sugar,—*Cane* and *Grape*, both of which yield alcohol by fermentation. Under this head are also comprised certain sugars of animal origin, viz., *lactin*, from the milk solely of the mammalia, and diabetic sugar, excreted in the urine of patients afflicted with diabetes.

Mannite (see MANNA) and Glycyrrhizin (see GLYCYRRHIZA), though not fermentescible, are yet so analogous to sugar in many other properties as to be considered a third species.

1. CANE SUGAR. *Syn.* Crystallizable sugar, Right polarizing sugar. Its chief sources are the sugar cane (*Arundo saccharifera*), the sugar maple (*Acer saccharinum*), and beet-root. It

also exists in the melon, carrot, pumpkin, and turnip, and in the palm and unripe Indian corn plants, and always as a primary secretion.

The yield of sugar varies with the kind of cane or raw material, the nature of the climate and soil in and upon which it is grown, the mode of cultivation, and process of manufacture. The amount obtained in the large way, ranges from 6—8 pr. ct. The proportion of sugar in saccharine juices can always be determined, however, and with sufficient accuracy for all practical purposes. The two most available methods, being equally applicable to refined and crude juices, are 1st, by fermentation, 2d, by circular polarization of light. These modes, as well as others, with directions for manipulating in detail, are given in R. S. McCulloh's excellent report to Congress, "*upon Sugar and Hydrometers*, 1848." In the same work are analyses of the juice of the different kinds of cane.

Prop. Crystallizes in oblique rhombic prisms, of $C_{12}H_{10}O_{10} + HO$, and spec. grav. 1.606. When refined is perfectly white, and exhibits phosphorescence by trituration in the dark. Very soluble in water, forming *Simple Syrup*, of spec. grav. 1.32 if the proportion of sugar is double that of the water. Only sparingly soluble in cold, and but very slightly so in hot alcohol. When the crystallization of syrup is gradual, the forms are large and definite, as in *Rock Candy*; but if the syrup is concentrated and the crystallization rapid, a crystalline mass results, as in *Loaf Sugar*. The presence of any acid prevents crystallization.

Pure sugar is unalterable by mere exposure at the ordinary temperature of the atmosphere, unless in the form of syrup, and then only after a protracted contact. This reaction renders it uncrystallizable, by transforming it into glucose, and ultimately into ulmin and ulmic acid, results which more quickly follow when the syrup is continuously heated in the open air to 200°, particularly when a minute quantity of acid is present. So also, when glucose is present, the addition of lime promotes these transformations. Solid sugar fuses at 350°, and congeals on cooling into *barley sugar*, which is at first amorphous, but in time becomes crystalline with the loss of its transparency. The density of this modified sugar is 1.505. Further heating renders it viscous without imparting color, until at 392° it decomposes into water, which vaporizes, and into a residual brown mass that at 428° blackens and becomes $C_{12}H_9O_9$, and hygroscopic. If the heat is applied suddenly instead of gradually, sugar is transformed into CARAMEL, water, formic and acetic acids; carbonic acid and oxide being probably concomitant products. Heated with lime, sugar yields METACETONE.

Cane sugar, in solution, rotates the plane of polarization to the right, and in this consists its distinction from grape sugar, which rotates to the left. Another characteristic is its property of being changed by acids, in the cold, into a peculiar sugar which polarizes from right to left. This inversion of the polarizing power by acid, is peculiar to cane sugar only.

Action of bases. Sugar unites with bases to form compounds, its water being displaced by

the combination. The lead compound is insoluble, and has the composition $2 PbO + C_{12}H_9O_9$. The baryta salt is crystalline, and has the formula $BaO, C_{12}H_{10}O_{10}$. The lime saccharate, $CaO, C_{12}H_{10}O_{10}$, is uncrystallizable, slightly soluble in cold, and but sparingly in hot water. Sugar also combines with chloride of sodium, forming an easily soluble compound, of the composition $NaCl, C_{12}H_{10}O_{10}$.

The dampness and inferiority of sugars is due to the presence of salt, for it imparts that property when the quantity contained is only one per cent.

Alkalies and alkaline earths, in limited proportion, yield compounds from which the sugar may be eliminated, unaltered, by the weaker acids; but if caustic alkali in excess be heated with syrup, the latter is transformed into ulmic and formic acids.

Action of Acids. Nitric acid generates successively *saccharic*, oxalic, and carbonic acids. Saccharic acid, when crystallized, is $C_{12}H_5O_{11} + 5 HO$. The formula of its lead salt is $5 PbO, C_{12}H_5O_{11}$, and that of its potassa compound $KO, C_{12}H_5O_{11} + 4 HO$. The transformation of sugar into oxalic acid has been made profitably available in the manufacture of sulphuric acid (see SULPHUR), its cost being defrayed by oxalic acid as a secondary or incidental product. Strong sulphuric acid carbonizes sugar, and produces sulphurous and formic acids, and two brown substances, *sacchulmin* and *sacchulmic acid*, both insoluble in water, and said to be isomeric with ulmin. If the acid is dilute and the temperature boiling, formic acid and ulmin are the products. Greater dilution of the acid and moderation of the temperature give glucose. Dilute hydrochloric acid also generates grape sugar. Arsenic acid colors syrup successively red, purple, and brown, the odor of acetic acid being simultaneously apparent. Sulphuretted hydrogen decolorizes this solution, by precipitating the arsenic.

Sugar possesses the property of preventing the precipitation of many metallic solutions by alkalies, the eliminated oxides being held by it in solution. When this solution is boiled, the oxides are partially reduced, and precipitated; in this manner the oxide in acetate of copper, and the acid in bichromate of potassa may be, respectively, reduced to red oxide of copper and oxide of chrome. The reducing power of sugar extends, likewise, to the metallic chlorides.

Caustic potassa added in excess to a mixed solution of cane sugar and sulphate of copper, strikes a blue color, not immediately alterable by heat; but if grape sugar is present, the application of warmth produces an abundant greenish precipitate of protoxide of copper, which passes into scarlet, and ultimately into dark red, leaving the supernatant liquid nearly colorless. This test, known as Trommer's, is an excellent one for distinguishing the two varieties of sugar.

Action of Ferments. Under the catalytic influence of yeast, rennet, casein, and protein compounds generally, sugar loses its sweetness, and is transformed into liquid sugar, gum, lactic and butyric acids, mannites, glucose, and ultimately into alcohol and carbonic acid.

SUGAR.

SUGAR.

Each of these transformations is a successive step towards the completion of the fermentation; but if the process is improperly conducted, the first change is to viscosity,—lactic acid is formed, and the alcoholic fermentation prevented. The proper proportions to insure a successful fermentation, are 1 sugar, 5 water, and 1 yeast, and the temperature 80°—90°. See FERMENTATION.

Preparation of Sugar from Cane. The first step is to grind the harvested cane between horizontal rollers. The great pressure at the same time exerted by this machine expels the juice from the crushed mass. To eject an additional portion, the marc should be further subjected to hydraulic pressure. If the locality abounds in fuel, so that the excess of water thus required may be evaporated economically, it will be advantageous to steep the pressed cane in water, and to subject it anew to the power of the mill and press. In this manner the yield of saccharine juice is greatly augmented. The usual proportion obtained is 40—70 pr. ct., according to the kind of cane and skill in manipulating. The greenish or grayish liquid running out consists of sugar, mucilaginous and albuminous matter, cerosie, salts, essential oil, and suspended matters. The solid portion or exhausted marc, technically termed *begassa*, is mostly lignin, retaining much of the pectin, and traces of the other constituents of the cane. This *begassa* is a useful residue, serving as fuel for the evaporation of the juice. In order to promote the separation or crystallization of the sugar from this heterogeneous juice, the latter is allowed to flow from the mill into a cold reservoir, whence, after sufficient repose for the settling of the suspended matters, it is transferred to filters, and the filtrate conveyed into the clarifying or defecating pan. The cold vat is dispensed with in many factories, the juice being passed directly from the mill into the clarifier. After being heated to 140° in this vessel, slaked lime is then added and thoroughly incorporated by stirring, after which the fire is cautiously increased, and ebullition continued until scum accumulates, and leaves a clear liquor beneath. The scum is to be skimmed off as fast as it arises. Cooling and repose follow; the clear, defecated liquor being then racked off into the grand copper. Other articles are substituted for lime, but none of them so effectual as the sulphate of alumina. The liquor is now passed through filters of appropriate construction, and the filtrate evaporated, to expel water, in hemispherical kettles heated by steam. Cleanliness and rapidity of action are conducive to the unalterability of the sugar by catalytic influence; and thus also, in this and every stage, are indispensable to the ultimate success of the process. When the required density is obtained by evaporation, the defecated syrup is then allowed to percolate through strata of bone-black. This latter treatment decolorizes the liquor, removes free acid, nitrogenous matters, excess of lime, and viscosity, promoting, in this manner, the granulation, and improving the color and quality of the sugar. A deposit, termed "*Cal*," attaches to the sides of the pan during the evaporation, and consists, according to Reynolds and Muckle, of—

	Reynolds.	Muckle.
Organic matter and water.....	69.16	68.19
Lime	19.68	21.71
Magnesia.....	4.66	3.65
Phosphate of iron, alumina, &c.	2.52	3.80
Insoluble matter, silica	0.13	0.11
Carbonic acid	0.95	0.60
	97.10	98.06

As the further application of heat and exposure of the syrup in the open pan would engender unprofitable modifications, the further concentration necessary to granulation must be effected so as to obviate them. Howard's vacuum pan, or Rillieux's series of pans accomplish these ends more readily and economically than others. The great economy and advantages of these apparatus are noticed at length in McCulloh's report to Congress, on sugars and hydrometers, and to that elaborate and valuable work the reader is referred for a full description of each, and of their *modus operandi*.

When the concentration is skilfully conducted and the liquor brought to "*proof*," it is then technically styled "*battery syrup*," and while yet hot is transferred to, or "*skipped*" into conical forms or moulds, located in a well lighted but close apartment, kept at a uniform temperature of 90°. As soon as a pellicle appears, it is to be diffused through the mass with a wooden stirrer. In this way the granulation proceeds gradually, but perfectly; after 25—40 hours, the cotton plugs at the opening of the smaller end or tip of the moulds are removed, so as to allow drainage off from the solidified mass of the mother water, or *Molasses*, into a cistern beneath. This mode of "*curing*" ensures perfect drainage, and by freeing the sugar of soluble saline matters renders it less deliquescent, and also removes the organic hygroscopic matter of Hervey. To displace any residual molasses, and thus to improve the color, grain, and dryness of the sugary mass, it is "*liquored*" with a light colored syrup of 31.5° B., which is to be poured on and allowed to percolate the contents of each mould. After drainage, the top or drier portion of the loaf is removed, conveyed to the drying room, and packed in hogsheads, as *brown sugar*, for the market. The lower or damp stratum is transferred to smaller moulds for renewed drainage, or else returned to the concentrating pan containing new syrup.

The molasses or treacle contains sugar, acetate and sulphate of potassa, chloride of potassium, phosphate of lime and of copper, mucilaginous and nitrogenous matters, silica, water, and glucose. It is either sent to market for domestic uses, or else is distilled into rum, or re-worked to extract an additional portion of sugar. The proportion of molasses to sugar, from the juice, augments with the neglect and deficiency of skill in manipulating,—the liquid and uncrystallizable sugars resulting from the transformation of the cane sugar during slow or imperfect manipulation.

The process recently announced by Melsens, Professor of Chemistry at Brussels, requires further testing before its practical utility can be fully determined. It consists in the use of

bisulphite of lime, which, when added to cane juice, is said to effect the separation and crystallization of the whole content of sugar. According to Melsens, it acts on the crushed cane juice—

"1st. As a powerful antiseptic, preventing the production or action of fermenting matter.

"2d. As, from its affinity for oxygen, capable of preventing the changes which the presence of that agent causes in the juice.

"3d. As an agent which, at 212°, defecates the juice, and removes from it all the albumen and coagulated matter.

"4th. As removing the pre-existing discoloration.

"5th. As an agent capable, in the highest degree, of preventing the formation of coloring matters.

"6th. As capable of neutralizing all the hurtful acids which may exist or be formed in the juice, substituting for them an almost inert (sulphurous) acid."

The impurities of brown sugar consist of sand, coloring and nitrogenous matters, uncrystallizable sugar, caramel, nitrate and acetate of potassa, chloride of sodium, carbonate, phosphate, and malate of lime, phosphate of magnesia, and sometimes acetic, malic, pectic, and lactic acids, saccharate of lime, and alcohol. The humidity of brown sugars is owing to the presence of saline matters, with which it forms deliquescent compounds. When these foreign matters are removed, the sugar becomes pure and snowy-white. This purification constitutes the process of—

Refining. Brown sugar is increased in sweetening power at least 30 pr. ct. by being refined. The first step is to crush the crude sugar in a mill, thence transfer it to a vat, and by a current of steam or "*blow up*," to "*melt*" it. The solution is treated, while hot, with 5 kilogrammes of fine bone-black to every quintal of sugar, and the mixture well incorporated by stirring. When ebullition commences, 1—2 pr. ct. blood, diluted with 4 volumes of water, are also added and stirred in for an half minute. The boiling being completed, the cock is opened and the hot mixture run off into filters of suitable form, best known as Taylor's filters. This procedure separates the finer parts of black, which may be washed with hot water and pressed out, to serve for another operation, or to be sold to farmers as "*black from refineries*." Its content of blood, porous carbon and phosphates, renders it a valuable manure.

A second filtration is now resorted to, through coarser black, and the filtrate is then concentrated in Howard's vacuum pan, which performs its work rapidly and without coloring the syrup. The concentrated syrup is drawn from the pans into conical moulds of earthenware, or of well-painted sheet-iron, with openings at their tips, closed with cotton plugs. These are ranged in series, and remain undisturbed in an airy room until the solidification of their contents, when they are removed to an apartment warmed to 80° by steam-pipes, and placed over reservoirs. The plugs being then removed and the apertures cleansed with a probe, drainage ensues gradually, until all the uncrystallized syrup has fallen through. This syrup, much used for domestic purposes,

is technically termed "green syrup," but is much better known in commerce as "*Steam refined syrup*," and is far superior to molasses in being sweeter, brighter, and very much purer.

After several days, or when drippings cease to flow, the base of each cone of sugar is smoothed with a trowel and then covered, to an inch depth, with a "*liquor*" of saturated syrup, made of fine white clarified sugar, which percolates the mass downwards, and displaces the colored syrup retained in the interstices of the granulated mass. Being already saturated, the "*liquor*" leaves the crystallized sugar untouched. The liquoring is repeated until the loaves have acquired the requisite whiteness, when they are removed from the moulds, brushed, and scraped or trimmed into symmetry if necessary, then placed in an inverted position for 24 hours, so as to equalize the diffusion of the residual liquor which subsides at the base, afterwards exposed to the air for a day, and removed to the drying room, heated by steam, where they must be protected from dust by loose paper covers. When the sugar first enters, the temperature of the drying chamber should not exceed that of the surrounding atmosphere; but as desiccation proceeds, the heat must be gradually increased to 113°. The chamber is allowed to cool slowly, and the loaves baked dry by this process are then removed to the packing room, where they are assorted into qualities or grades, according to color, and wrapped in white paper with blue envelopes, preparatory to being packed for market. Those loaves which are condemned by inspection as too much colored, are reduced to small lumps, and sold as "*crushed sugar*."

Preparation of Sugar from Beets. Payen's quantitative analysis of beet-root gives, as its composition,—water, 83·5; sugar, 10·5; cellulose, 0·8; and silica, saline, coloring, gummy, and fatty matters, malic acid, albumen, casein, chlorophyll, and asparamide to the amount, total, of 5·2. The proportion of sugar obtained by the processes employed for its extraction, on a large scale, rarely reaches 10 pr. ct., and is frequently not over 5 pr. ct.

The first step in the process of manufacture is to cleanse the beets with water, in a revolving cylinder. The adherent dirt being thus removed, the beets are reduced to pulp by a rotary rasping machine, and the pulp is then bagged and subjected to gradual pressure between iron plates, under a hydraulic press. In this way 75—80 pr. ct. of juice is obtained, but the quantity may be increased by steaming or macerating the pressed cake in water, and re-pressing it. The water acts by displacing the juice retained in the unbroken cellules, and in the interstices of the pulp. To avoid any transformation of sugar during the process, the bags are occasionally dipped in water containing 2—3 thousandths of tannin.

Previous to the steaming or maceration, the bags are subjected, in layers of two between each pair of plates, to a second but more powerful pressure, gradually applied. The pulp thus exhausted serves either as food for hogs, or as a fertilizing agent for soils.

The expressed juice is immediately conveyed to a double-bottomed pan heated by steam.

Any unnecessary delay in the transfer may cause a deterioration of the juice, under the catalytic influence of nitrogenous ingredients. The temperature is then raised as rapidly as possible to 140°—160°, and milk of lime added to and stirred into the hot juice. The proportion of lime varies with the nature of the beet and amount of free acids. As soon as ebullition commences, the heat must be stopped off, otherwise the liquor becomes so connected with the lime flocculæ as to render their separation impossible. The lime acts by neutralizing the free acids, by combining with the albuminous, gummy, and nitrogenous matters, to form insoluble products; by eliminating casein, fatty and coloring matters, and by decomposing the salts of ammonia, of soda, and of potassa, and by promoting the separation of the coagula to the surface, as scum. Care, too, must be taken not to use an excess of lime, otherwise subsequent evaporation will be difficult, and the amount of molasses will also be increased.

The defeated juice is then evaporated in vacuo to 25° B., refiltered through fresh bone-black to remove color and insoluble matters, thence conveyed into vacuum pans to be concentrated. When the syrup has arrived at "proof" it is drawn off into coolers, and as soon as crystallization commences the mass is well stirred, and at 120° is transvased into conical moulds similar to those used in refining cane sugar, and drained, as before described, in an apartment heated to 80°—90°. The contents being then emptied out and dried, constitute rough sugar for the market or refinery. The drained liquor or molasses is used for making rum or caramel.

Preparation of Sugar from the Maple. This sugar has a peculiar, agreeable flavor, and may be refined to absolute whiteness. The sap is drawn in February and in the early part of March by boring the trees, near their bases, with oblique holes of an inch diameter, and to half an inch beyond the alburnum. The juice which exudes is collected in troughs, and thence transferred to large reservoirs, from which it is transvased, before fermentation ensues, into pans, and evaporated to syrup, care being taken to remove the scum as it arises. The syrup, after cooling, is filtered, and the filtrate is further concentrated to its crystallizing point, and then poured into granulating vessels or moulds. After crystallization and drainage, it is emptied out and dried.

Sugar from Indian Corn. Mr. Webb has given the results of some experiments for extracting sugar from corn stalk, in the Patent Office Report for 1844.

Good crystallizable sugar can be made from corn, but it is tolerably certain that its manufacture would not yield as profitable a return as the same extent of ground employed for other crops.

2. GRAPE SUGAR. Syn. Glucose, Sucre mameionnè, Sugar of honey—of starch, Diabetic sugar, Uncrystallizable sugar, Chulari-ose. This sugar exists naturally in grapes and in the juice of many ripe fruits, imparting to them their sweetness. It is also found in the urine of diabetic patients, and may be formed artificially by the catalytic action of diastase on starch or cane sugar, or of dilute sulphuric

acid upon starch, lactic, gum, or lignin. Cane sugar passes into grape sugar when changing into alcohol by fermentation, and this accounts for its presence in molasses. The term grape sugar, in a limited sense, belongs properly and only to sugar from grapes; but as it is a mooted point, whether the slight discrepancies between the several different sugars classed under this head are irreconcilable, most chemists have assumed their identity, and so we accordingly give the name its general application. The grape sugar from starch, however, differs from ordinary glucose in rotary power. "Liquid sugar" is that species of glucose which is uncrystallizable, but solidifies on evaporation.

Prep. Four parts of water acidulated with $\frac{1}{100}$ — $\frac{1}{10}$ of oil of vitriol are treated, while boiling, with 1 pt. of finely-powdered starch, gradually added and thoroughly stirred in. After boiling some time (30—40 hours, if the quantity be large), the paste first formed becomes dextrin and fluid, and as soon as the latter ceases to be precipitated by alcohol, it is completely neutralized with chalk, filtered, concentrated to a dense syrup, and set aside to solidify on cooling. During the cooling its expansion is so great as to break the cooler, if it is fragile.

Glucose may also be made by treating starch paste for several hours at 140°—160°, with an infusion of malt.

Prop. Formula $C_{12}H_{14}O_{14}$. Spec. grav. 1.39. Congeals into acicular granules, less soluble in water than cane sugar. Is also more fusible and less alterable. Soluble in 20 pts. boiling, absolute alcohol, but separates on cooling, combined with a portion. In sweetening power, its ratio to cane sugar is as 60 to 100. Polarizes to the left. Grape sugar does not blacken into molasses by evaporation, but at 212° it loses 2 eqs. of water, becoming *carpomel*. At a higher heat, caramel is formed.

Grape sugar unites with bases yielding very alterable compounds. It may, however, unlike cane sugar, be entirely transformed by alkalies and alkaline earths, into brown matter. Caustic potassa, as well as lime, generate *glucic* acid, $C_{12}H_{12}O_8$, soluble in water, uncrystallizable, and giving neutral, soluble salts with baryta, lime, and lead. Melassic acid, $C_{24}H_{12}O_{10}$, is also simultaneously formed with glucic acid, but little is known of it except that it is in black floccule.

Strong sulphuric acid dissolves glucose without color, producing *sulphosaccharic* acid, which gives a lead salt of composition $2(C_{12}H_{11}O_{11}) + SO_3 + 4PbO$.

3. LACTIN. Syn. Sugar of Milk. This substance, though of animal origin, may be, by reason of its analogy, classed as a variety of sugar. It exists only in the milk of the mammalia, and may be separated as follows:—

Prep. By removing the casein from milk, decolorizing the serum or whey by charcoal, clarifying with albumen, filtering, and concentrating to syrup. After repose the syrup crystallizes, and the mass is then to be purified by re-solution and re-crystallization.

Prop. Formula $C_{24}H_{24}O_{24}$. Crystallizes in white, square prisms, of spec. grav. 1.54. Soluble in water, insoluble in alcohol and in

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ether. Yields alcohol by fermentation. At 212° loses nothing, but at 300° becomes $C_{24}H_{19}O_{19}$. By action of hot, dilute acids, it becomes grape sugar, and by nitric acid is changed to mucic or saccholactic acid. Combines with ammonia and metallic oxides, forming with lead a soluble and insoluble compound. With alkalis it reacts like glucose. Possesses the property of preventing the precipitation of many metallic solutions.

4. ERGOT SUGAR. Formula $C_{12}H_{13}O_{13}$. Wigger's mushroom sugar, obtained from ergot, crystallizes in transparent, rhombic prisms. Is fermentable into alcohol, and soluble in water and in alcohol. It does not precipitate suboxide of copper from a boiling solution of acetate. Braconnot's mushroom sugar has been found to be mannite.

For details of the manufacture of sugar, see *Dumas' Chimie*, *Sugar Planters' Manual*, *Payen's Chimie Industrielle*, and *McCulloh's Report on Sugars and Hydrometers*.

SULPHAMETHYLAN. See METHYL.

SULPHAMIDE. See AMIDE.

SULPHANTIMONIC ACID. See ANTIMONY.

SULPHARSENIOUS } ACID. See ARSENIC.

SULPHARSENIC }

SULPHATOCARBONATE OF LEAD. See

DIOXYLITE AND LEADHILLITE.

SULPHINDIGOTIC ACID. See INDIGO.

SULPHOBENZIDE. See BENZOLE.

SULPHOCYANOGEN, } See CYANOGEN.

SULPHOCYANIDES, }

SULPHOCYANIC ACID. }

SULPHOMESITYLIC ACID. See ACETONE.

SULPHOPURPURIC ACID. See INDIGO.

SULPHOVINIC ACID. } See ETHYL, p. 605.

SULPHOVINATES. }

SULPHUR. *Chem.* Brimstone. *Ger.* Schwefel. *Fr.* Soufre. The two principal technical operations connected with sulphur are its extraction, and the manufacture of oil of vitriol or sulphuric acid.

EXTRACTION OF SULPHUR.

Sulphur is found native in the vicinity of active and extinct volcanoes. Those districts which furnish it in greatest abundance to commerce are the vicinity of Naples and the South coast of Sicily, where it is found in layers of marl. The *fumaroles* or gaseous exhalations bring up sulphur from below, and deposit it at the cooler surface of the earth. Sicily furnishes about 77,000 tons annually; Naples and Tuscany less. The mixed sulphur and earth are put into an earthen retort (an upright jar with a beak), the cover luted on, and the beak passed into another upright jar. The retorts are placed in rows in a furnace, wide enough to receive two rows, in which they are heated by an open fire. The sulphur sublimes, condenses in the receivers, and flows out from them into a vessel filled with water, where it congeals. The crude sulphur thus obtained is repurified in a large iron pot, (holding $\frac{1}{2}$ a ton of sulphur), built in brick-work, and connected by a wide opening with a brick chamber. When the pot is heated to 302° the sulphur fuses, and takes fire and burns as long as there is oxygen present in the chamber to feed the flame; when the heat rises to above 600° , the sulphur boils, rises in vapor, and condenses as flowers of sul-

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phur on the walls of the chamber, but when these become heated, the greater part of it condenses into a liquid at the bottom of the chamber. From this it is run into sticks. A small amount of sulphur is distilled in Germany from iron pyrites, in earthen tubes, many of which are built up in a stack or bench with their ends projecting, from which the sulphur collects in water.

OIL OF VITRIOL.

Sulphuric acid is usually made from the combustion of sulphur under peculiar circumstances, or more rarely by the distillation of copperas, or protosulphate of iron. The former yields the common or English oil of vitriol, the latter the fuming or Nordhausen acid.

Fuming sulphuric acid. The mother liquors from the crystallization of copperas are concentrated, and the impure salt thus obtained is subjected to distillation. The form. of copperas is $FeO, SO_3 + 7 HO$, and by careful heat the 7 HO may be driven off, leaving the dry salt. The salt is charged into small earthen retorts, many of which are built up in a stack, and a high heat given. Sulphurous acid chiefly passes over first, and when white fumes of sulphuric appear, the retorts are connected with their receivers, and a high heat continued for some time, during which the fuming oil of vitriol passes over and condenses. The theory of the process is simple. During the first heating of the retorts, a portion of the sulphuric acid gives up oxygen to the protoxide of iron converting it into peroxide, while sulphurous acid passes off, the sulphate of the peroxide then yields up its sulphuric acid, which passes over with remaining water, and leaves peroxide of iron, *Colcothar*, in the retorts. For the nature of this acid, see below.

English oil of vitriol. The combustion of sulphur produces sulphurous acid, to convert which into sulphuric, nitrous fumes are used, derived from the decomposition of nitric acid, and as a lower oxide of nitrogen forms after the fumes have given up oxygen, this is again oxidized by atmospheric air. To assist the whole change and collect the acid, steam is employed. The formation takes place in chambers, composed of heavy sheet-lead, which are from 25—100 ft. long, 15—50 ft. wide, 15—25 ft. high. The sulphurous acid is usually obtained by burning sulphur on a furnace-hearth, the fumes of which, mixed with atmospheric air are directly conducted into the first chamber. The high price of sulphur a few years since suggested the use of pyrites instead of it, and the manufacture of the acid from pyrites was successfully carried out in England. It may be burned on a flat hearth; or in a vertical kiln, which acts perpetually, being charged from above, while the burned stone is drawn out below. The nitric fumes were formerly obtained by mixed 6—12 lb. saltpeter with 100 sulphur. The saltpeter was afterward put in a separate vessel above the burning sulphur, and mixed with oil of vitriol to develop nitric acid, the heat both liberating and decomposing the nitric acid in part. But it is found that nitric acid itself put in shallow dishes in the chambers converts sulphurous into sulphuric acid; $NO_5 + 3 SO_2 = NO_2 + 3 SO_3$. Another

mean of developing nitrous fumes was to act on sugar or molasses by nitric acid, whereby the residue yielded a large quantity of oxalic acid, but unless this acid bear a high price, the process is not economical.

While the nitric fumes, sulphurous acid and air enter the chambers, steam is admitted at the same time. The liquid acid on the bottom of the chamber is allowed to attain the density of 1.558 (52° B.), when it contains 54 pr. ct. pure oil of vitriol or simple hydrated acid. As the oxygen of the air in the chambers is consumed, in oxidizing nitric oxide, and nitrogen remains, a draft must be maintained in the whole range, both to carry it off, and to draw in the sulphurous acid, fresh air and nitrous fumes. Hence a considerable amount of nitrous fumes is carried out with the escaping nitrogen. A late improvement obviates much of this loss. It consists of a series of vertical columns filled with coke, through which the waste gases pass up and down, and where a portion of nitrous fumes is condensed. A jet of steam at the exit of the last pipe causes a current through the whole range of chambers and columns.

Theory of the Process. The nitrous fumes entering the chambers are chiefly peroxide of nitrogen, NO_2 , and give up to sulphurous acid one eq. oxygen, while they are reduced to nitric oxide; $\text{NO}_2 + 2 \text{SO}_2 = \text{NO} + 2 \text{SO}_3$. But nitric oxide combines with anhydrous sulphuric acid to form NO_2 , 2SO_3 , and this again unites with oil of vitriol to form a white crystalline body, of the composition, NO_2 , $2 \text{SO}_3 + \text{HO}$, SO_3 . Large quantities of this crystallized body are often found in the chambers. The action of steam however decomposes this compound, NO_2 , $2 \text{SO}_3 + \text{HO}$, $\text{SO}_3 + 3 \text{HO} = 4 (\text{SO}_3, \text{HO}) + \text{NO}_2$, converting it into oil of vitriol, while nitric oxide escapes. This oxide is again converted by the oxygen in the air of the chambers into red fumes, NO_2 , which again transform a portion of sulphurous into sulphuric acid.

Concentration. The liquid from the chambers is evaporated, to remove water, first in leaden pans and finally in a platinum still. The pans are broad and shallow, usually set in a series of 2 or 3, and their bottoms supported and protected by a thick iron plate. The lowest is partly over the fire, the next one a little higher, and the third still higher, thus allowing the flame to play under all at the same time. The acid which is run into them has a spec. grav. = 1.55, and is concentrated in them to 1.7, when it is run into the platinum still. Leaden pans are objectionable from the quantity of lead dissolved by the acid, and from the loss of acid. By covering them with a movable hood of sheet lead, a saving of 10 pr. ct. of acid has been effected, and by passing the products of combustion over instead of under the pans, set in brick-work, the concentration is more rapid, and there is less loss to the pans. The acid is concentrated in the still to 1.815 (66° B.). When the process is well conducted 1 lb. sulphur will produce 3 lb. oil of vitriol of this strength, and require only 0.03 lb. of nitrate of soda. It is difficult to estimate the quantity of oil of vitriol made; but one establishment may produce more than 100 tons of oil of vitriol per week.

SULPHUR AND ITS COMPOUNDS.

1. *Sulphur.* It occurs in two forms in commerce, in masses or sticks, fused sulphur, *rolled brimstone*, and in a fine powder, deposited from the vapor of sulphur, called *flowers of sulphur*. It crystallizes in two forms, and may also be amorphous. The native crystals, and that obtained from solution in bisulphuret of carbon, are right rhombic, usually showing an acute 8-hedron modified by a prism and end-planes; spec. grav. 2.0—2.07; when sulphur is fused, cooled until a crust forms on the surface, the crust then pierced and the interior still fluid portion poured out, it forms long prisms in the cavity, belonging to the oblique rhombic system. Flowers of sulphur are minute, amorphous globules. Sulphur fuses at 221°—233° to a yellow, transparent, thin liquid (spec. grav. 1.927); at 320° it begins to be thicker and more orange-colored, and increases in these appearances until, between 428° and 500°, it is dark reddish brown, nearly opaque, and so thick that it will not run out of the vessel; at a higher heat it becomes thin again, but not as thin as above 221°; at 822° it boils and rises in a deep orange-colored vapor, which deposits flowers of sulphur on a cold body. When fused and heated to about 400°, and poured into cold water, it forms a transparent, flexible and elastic mass of a yellow color, which sometimes retains its elasticity for days, if undisturbed. When sulphur is precipitated from alkaline sulphurets, it is a grayish white powder. Sym. S. Eq. = 16 (16.06 H = 1; 200.75 O = 100. *Berz.*)

2. *Oxides.* a. *Sulphuric acid.* See its manufacture above. Anhydrous sulphuric acid is obtained by heating fuming oil of vitriol in a glass retort, to which is attached a receiver cooled by ice. The first portions are anhydrous, and condense as a mass of white, needle-shaped crystals. It is also formed by passing a mixture of sulphurous acid and atmospheric air over heated platinum sponge. Fusible, boiling at about 130°, rising in colorless vapor, (spec. grav. 2.773), but in the air as a white vapor from the condensation of water, hisses when thrown into water, from its powerful attraction for water. It is decomposed into oxygen and sulphurous acid when passed through an ignited porcelain tube, or over heated mercury. Its composition in equiv., pr. et., and volume is

	Eq. in 100 pts.		By vol.
S	16	40	2210.4
O ₃	24	60	3315.6
SO ₃	40	100	2)5526.0
			2763.0

The spec. grav. 2763, is a little below that found by experiment. The vapor of sulphur as found by Dumas and Mitscherlich is 6617 and 6900, but it is the spec. grav. of the vapor of one of the allotropic conditions of sulphur, that derived from the brown-heated sulphur, but sulphur rises in vapor below this point, and its grav. has not been determined. If the eq. of S.: spec. grav. in gas :: eq. ox. spec. grav. of ox. (8 : 1105.2 :: 16 : 2210.4) then its spec. grav. is $\frac{1}{3}$ of that found by experiment. By a comparison of sulphuretted hydrogen with

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oxide of hydrogen or water, we attain nearly the same number for the spec. grav. of sulphur, namely 2244. Whence it is probable that the spec. grav. of vapor of sulphur in the state in which it combines to sulphuric acid, &c., is $\frac{1}{3}$ of that at which it is usually taken, as resulting from experiment.

Fuming oil of vitriol is probably a mixture of anhydrous, with hydrate and a subhydrate. When the subhydrate is distilled off, it is followed by anhydrous acid with a little hydrate, but a definite subhydrate is formed by mixing common oil of vitriol and the anhydrous acid. It has the form. $\text{SO}_3 + \text{HO}$, $\text{SO}_3 = \text{HO}$, 2SO_3 , and is crystallizable.

Common oil of vitriol, when concentrated as much as possible, has the form HO , SO_3 (eq. = 49), but the strongest commercial acid contains

only about 92—94 pr. ct. of the true hydrate. Spec. grav. of the pure hydrate = 1.848, of the ordinary commercial less 1.81—1.84, the latter often due to substances in solution. It congeals at -130° , boils at 600° — 619° . 1 eq. sulphuric acid with 2 eq. water form a liquid, of spec. grav. 1.78, crystallizable at about 45° ; form. HO , $\text{SO}_3 + \text{HO}$. Another compound of HO , $\text{SO}_3 + 2 \text{HO}$ has a spec. grav. 1.632. Oil of vitriol becomes heated by mixture with water, hence the care required in making the mixture in glass vessels. It attracts about 15 times its weight of water by exposure to the air, whence its use in drying substances for experiment. The following table by Ure shows the content of oil of vitriol (the simple hydrate) and of anhydrous acid in acid of different densities.

Liquid.	Sp. grav.	Dry.	Liquid.	Sp. grav.	Dry.	Liquid.	Sp. grav.	Dry.
100	1.8460	81.54	66	1.5503	53.82	32	1.2334	26.09
99	1.8438	80.72	65	1.5390	53.00	31	1.2260	25.28
98	1.8415	79.90	64	1.5280	52.18	30	1.2184	24.46
97	1.8391	79.09	63	1.5170	51.37	29	1.2108	23.65
96	1.8366	78.28	62	1.5066	50.55	28	1.2032	22.83
95	1.8340	77.46	61	1.4960	49.74	27	1.1956	22.01
94	1.8288	76.65	60	1.4860	48.92	26	1.1876	21.20
93	1.8235	75.83	59	1.4760	48.11	25	1.1792	20.38
92	1.8181	75.02	58	1.4660	47.29	24	1.1706	19.57
91	1.8026	74.20	57	1.4560	46.48	23	1.1626	18.75
90	1.8070	73.39	56	1.4460	45.66	22	1.1549	17.94
89	1.7986	72.57	55	1.4360	44.85	21	1.1480	17.12
88	1.7901	71.75	54	1.4265	44.03	20	1.1410	16.31
87	1.7815	70.94	53	1.4170	43.22	19	1.1330	15.49
86	1.7728	70.12	52	1.4073	42.40	18	1.1246	14.68
85	1.7640	69.31	51	1.3977	41.58	17	1.1165	13.86
84	1.7540	68.49	50	1.3884	40.77	16	1.1090	13.05
83	1.7425	67.68	49	1.3788	39.95	15	1.1019	12.23
82	1.7315	66.86	48	1.3697	39.14	14	1.0953	11.41
81	1.7200	66.05	47	1.3612	38.32	13	1.0887	10.60
80	1.7080	65.23	46	1.3530	37.51	12	1.0809	9.78
79	1.6972	64.42	45	1.3440	36.69	11	1.0743	8.97
78	1.6860	63.60	44	1.3345	35.88	10	1.0682	8.15
77	1.6744	62.78	43	1.3255	35.06	9	1.0614	7.34
76	1.6624	61.97	42	1.3165	34.25	8	1.0544	6.52
75	1.6500	61.15	41	1.3080	33.43	7	1.0477	5.71
74	1.6415	60.34	40	1.2999	32.61	6	1.0405	4.89
73	1.6321	59.52	39	1.2913	31.80	5	1.0336	4.08
72	1.6204	58.71	38	1.2826	30.98	4	1.0268	3.26
71	1.6090	57.89	37	1.2740	30.17	3	1.0206	2.446
70	1.5975	57.08	36	1.2654	29.35	2	1.0140	1.63
69	1.5868	56.26	35	1.2572	28.54	1	1.0074	0.8154
68	1.5760	55.45	34	1.2490	27.72			
67	1.5648	54.63	33	1.2409	26.91			

Sulphates. Sulphuric is the most powerful acid, and for this reason, as well as its cheapness, is the most important agent in chemical decompositions, being either employed directly, or being used to obtain other agents, as muriatic, nitric acids, &c., for this purpose. It combines with bases evolving heat, amounting with baryta and magnesia, even to ignition. The neutral sulphates of alkalies, alkaline earths, of manganese, lead and silver are neutral, the others redden litmus paper. Some of them by heat lose their acid as such, or as sulphurous acid and oxygen. By heating with charcoal, the alkaline and some others are reduced to sulphurets, the rest generally to metal. Hydrogen, phosphorus and some metals act similarly.

In solution with organic matter, they often decompose and evolve sulphuretted hydrogen, carbonic and acetic acids, &c. Acids more fixed by heat, as phosphoric, silicic, boracic, expel the acid of sulphates when heated with them, partly unaltered, partly decomposed. Sulphuric acid forms bi- and tri-salts, all soluble in water, basic salts insoluble in water, but soluble in muriatic acid, and neutral salts, the greater part of which are soluble; those of baryta, lead, and strontia, almost insoluble, of lime and silver slightly soluble. All the solutions of sulphates give a white precipitate with a soluble salt of baryta, the limit of the test being about 1 pt. of the sulphate to 100,000 pts. water at once, or 200,000 pts. after 15—20

minutes. The sulphates are generally insoluble in alcohol.

b. Sulphurous acid. Syn. Vitriolic air, Phlogisticated vitriolic acid. *Ger.* Schweflige Säure. It occurs in the vicinity of volcanoes, and is formed by burning sulphur in the air. It is prepared by heating oil of vitriol with charcoal, sawdust, copper, or mercury, or by heating sulphur and binoxide of manganese; the gas from charcoal and sawdust is mixed with carbonic acid. It is caught over mercury as a gas, or absorbed by water for the liquid acid. The gas is colorless, not inflammable, of a peculiar, penetrating odor, spec. grav. 2.210; form. SO_2 . When passed into a U tube, surrounded by a mixture of snow and salt, it condenses into a liquid, of spec. grav. 1.45, boiling at 14° . By evaporating the liquid under the air-pump, a portion solidifies to white flocks; the same is better obtained by surrounding the vessel with a mixture of solid carbonic acid and ether. Water absorbs nearly 40 times its volume of the gas, and holds it partly even after ebullition, but by exposure it is oxidized to sulphuric acid. It crystallizes from a saturated solution a little above 32° , with the form. $\text{SO}_2 + 9\text{HO}$.

It bears a high temperature without decomposition, but if moist separates into sulphuric acid and sulphur; heated with hydrogen, it produces water and sulphur, with phosphorous acid it forms phosphoric acid and sulphuretted hydrogen. Zinc, tin, and iron extract oxygen from it, and form dithionous acid; it precipitates the precious metals from solution, iodine from iodic acid, and both by this acid and nitric it is changed to sulphuric acid. All these reactions are due to its affinity for oxygen, and this further shown by its conversion into dithionic acid by binoxide of manganese, and into sulphuric by peroxide of lead. This last is the most convenient agent to extract it from gaseous mixtures.

Sulphites. They resemble the corresponding sulphates. The neutral alkaline salts have an alkaline reaction, the acid salts a neutral reaction. The neutral salts of the alkalis only are soluble in water, but the other insoluble sulphites are soluble in muriatic acid; the acid salts are all soluble. The sulphites tend to oxidize in the air to sulphates, and are changed similarly to sulphurous acid itself.

Uses. The gas is employed in bleaching straw and silk, to which it also imparts a gloss. The color is not deoxidized, for it is restored by an alkali or stronger acid. The gas is also used in France as a bath for diseases of the skin.

c. Dithionic acid. Hyposulphuric. *Ger.* Unterschwefelsäure. Form. S_2O_5 .

Prep. Bin oxide of manganese freed from hydrate by nitric acid is ground to a very fine powder and suspended in water; sulphurous acid gas is slowly passed through the water cooled artificially. Hyposulphate of manganese is in solution $\text{MnO}_2 + 2\text{SO}_2 = \text{MnO}, \text{S}_2\text{O}_5$. The manganese is separated by sulphuret of barium, and the solution of hyposulphate of baryta evaporated to dryness and weighed. To every 100 pts. of this salt dissolved in water 18.78 pts. oil of vitriol, diluted with 3 to 4 times as much water, are added, or until all the baryta is thrown down. The liquid is evapo-

rated in vacuo over sulphuric acid until it has the density 1.347. It is a very unstable acid, changing in the air and by ebullition.

Dithionates. They are all soluble in water, permanent in air, unaltered by oxidizing agents unless heated with them. The salts are most conveniently formed from that of baryta by adding its solution to that of a metallic sulphate.

d. Dithionous acid. Hyposulphurous acid. *Ger.* Unterschweifige säure. Formula S_2O_2 . It has not been isolated, for as soon as separated from its bases, it is resolved into sulphur and sulphurous acid. Its salts, see under SODIUM, SILVER, &c. They are readily decomposed by heat and acids. Its silver-salt is remarkable for sweetness, and its presence may be known by its dissolving fresh chloride of silver, and imparting a sweet taste to the solution. The hyposulphite of strontia is soluble in water, a property which serves to distinguish this acid from sulphurous and sulphuric.

e. Trithionic acid. Langlois' acid. $\text{S}_3\text{O}_5 = \text{S}_2\text{O}_5 + \text{S}$. It is obtained by digesting flowers of sulphur with bisulphite of baryta for several days, at a temperature not exceeding 122° , cooling to crystallize the salt, and decomposing this exactly with sulphuric acid. The solution may be concentrated by evaporation in vacuo over oil of vitriol. It is readily decomposed by heat, and by nitric and chloric acids. It is precipitated black by salts of suboxide of mercury.

f. Tetrathionic acid. Acid of Fordos and Gelis. $\text{S}_4\text{O}_5 = \text{S}_2\text{O}_5 + \text{S}_2$. Obtained by dissolving iodine in hyposulphite of baryta, and crystallizing the new salt, which is less soluble than iodide of barium; the change is $2(\text{BaO}, \text{S}_2\text{O}_2) + \text{I} = \text{BaI} + \text{BaO}, \text{S}_4\text{O}_5$. The acid is obtained by precipitating the baryta by sulphuric acid. This acid may be concentrated more than the other polythionic acids, but its salts appear to be less stable than the acid itself.

g. Pentathionic acid. Thomson and Wackenroder. $\text{S}_5\text{O}_5 = \text{S}_2\text{O}_5 + \text{S}_3$. Pass sulphohydrogen through a strong solution of sulphurous acid until it has the odor of the former, and evaporate, putting in copper to remove suspended sulphur, to the density 1.37. It is decomposed by heat and by strong bases. It is distinguished from hyposulphurous acid by not acting on iodine. Its salts are less soluble than the hyposulphites.

3. *Hydrogen.* *a. Sulphohydric acid.* Hydro-sulphuric acid, Sulphuretted hydrogen, Sulphohydrogen. *Ger.* Schwefelwasserstoff, Wasserstoffsulfid. Form. HS. *Prep.* As hydrogen may be obtained by the action of dilute sulphuric acid on potassium, iron, zinc, &c., so this gas is generated by the action of the same acid on the sulphurets of those metals, the most convenient of which is sulphuret of iron: $\text{FeS} + \text{SO}_3, \text{HO} = \text{FeO}, \text{SO}_3 + \text{HS}$. As this sulphuret is artificial, it usually contains metallic iron, so that the gas is mixed with hydrogen. To obtain it pure, heat 1 pt. sulphuret of antimony with 4 pts. muriatic acid, and wash the gas in water. It may be collected over water at 80° , or over a solution of salt. Before passing the gas from sulphuret of iron

into a solution, it should be washed in an intermediate bottle of water, to prevent particles of iron from passing over.

Prop. A colorless gas, of a strong and nauseous odor; spec. grav. = 1191; by a pressure of 17 atmospheres at 50°, it condenses to a limpid liquid of spec. grav. 0.9; by a cold of -122°, it becomes a white, crystalline solid. Although offensive, it may be inhaled by men, when largely mixed with air, without apparent injury; and I have known it to be inhaled in large quantity, when fresh, without producing further harm than a temporary faintness. The effect upon one operative was to produce a pleasant lethargic feeling, from which he expressed a regret that he had been awakened. I have breathed a strong admixture of it with air repeatedly, and never experienced the slightest evil result. It is said by Thenard, that birds are killed by $\frac{1}{1500}$ in the air, and dogs by $\frac{1}{800}$. I doubt the latter result, unless they are confined in it. When the gas from sulphuret of iron has been passed through an acid solution, and the latter has stood for 24 hours or more, the odor which it emits is totally distinct from that of sulphohydrogen. When thus employed on a large scale, the stale gas affects the eyes precisely like the oil of mustard, causing a flow of tears and acute pain. May not this effect be attributed to a sulphuretted organic compound, arising from the carbon in the mixed cast and wrought iron, from which the sulphuret of iron was made? (*J. C. B.*) Water, at 64°, dissolves $2\frac{1}{2}$ times, and alcohol 6 times its volume of this gas. The solution is colorless, has the odor of the gas, and a peculiar sweetish taste. By exposure to air the hydrogen is oxidized and sulphur deposited, producing an opalescence or milkiness in the liquid.

Passed through an ignited porcelain tube, it is resolved into sulphur and hydrogen gas, of the same volume as the original gas. It is very combustible, burning with a pale blue flame, and forming water and sulphurous acid. Acids, and many other bodies containing oxygen, decompose it by oxidizing its hydrogen, and sometimes more or less of its sulphur. Thus bromic and iodic acids produce with it water, sulphur, and the halogen; the iodates, bromates, and hypochlorous acid, the same with sulphuric acid; nitric and some nitrates, water, sulphur, sulphuric acid, nitric oxide, and ammonia; the halogens produce a hydracid and sulphur, or sulpho-halogen, and if water be present, also sulphuric acid. Tin heated in the gas becomes sulphuret, and sets free all the hydrogen; many oxides heated in it produce a similar result. It decomposes perfectly a large number of metallic oxides in acidulated solution, cadmium, lead, bismuth, copper, mercury, silver, gold, platinum, tin, antimony, and arsenic, precipitating them as sulphurets; from alkaline solutions the last five are not precipitated, while others are, as nickel, cobalt, iron, manganese, uranium, and zinc; peroxide of iron, in solution, is reduced to protoxide, and sulphur precipitated. In these precipitations the above oxidizers of sulphohydrogen should be avoided, especially nitric acid, which is so often employed in analytic processes. See ANALYSIS.

b. Bisulphide of hydrogen, HS₂. Sulphuret of potassium (made by fusing pearlash with half its weight of sulphur) is dissolved in water, and poured in a small stream into muriatic acid diluted with 2 or 3 vols. of water; while chloride of potassium goes into solution, the bisulphohydrogen precipitates as a yellow, oily liquid. In its chemical relations, it resembles binoxide of hydrogen.

4. Halogens. There are five chlorides of sulphur, three of which can be isolated. *a. Subchloride, S₂Cl.* It is obtained by passing chlorine into a cylinder containing dry flowers of sulphur on the bottom, and kept cold by ice-water until it is saturated, and then distilling in a retort; or it is obtained by distilling 6 pts. chloride of mercury with 2 pts. bichloride of tin and 1 pt. sulphur. It is a reddish yellow liquid, of a peculiar and disagreeable odor, fuming in the air, spec. grav. 1.628; boils at 282°, spec. grav. of gas 4664; it decomposes gradually, with water, into muriatic acid, sulphur, and hyposulphurous acid; it dissolves sulphur, selenium, and phosphorus.

b. Chloride, SCl. Is obtained from the subchloride, which is put into a retort connected with a receiver, and chlorine in excess passed over it for several days. It is then distilled at between 140° and 158°, and rectified until its boiling point has attained 147°. It is a darker liquid than *a.*, decomposes similarly with water, forming polythionic acids, &c. When it is kept in a retort heated to 131°, while air passes through, chlorine is evolved, and the heat may be raised to 158°. It is then distilled over a red liquid of the form. S₂Cl₃, or rather S₂Cl + 2 SCl. Two other chlorides of sulphur exist, but only in combination.

c. Bisulphate of terchloride. Sulpho-biachloride. SCl₃ + 2 SO₃. Obtained by several weeks exposure to sun-light, a mixture of sulphurous acid gas with a little more than its volume of chlorine; or sooner by passing mixed sulphurous and olefant gases into a vessel full of chlorine. It is a colorless liquid, of strong odor, boiling at 170.6°, decomposed by water and alcohol into sulphuric and muriatic acids.

d. Pentasulphate of terchloride. Sulpho-quinquachloride. SCl₃ + 5 SO₃. Obtained by passing anhydrous sulphuric acid into subchloride of sulphur, *a.*, below 32°, until the acid deposits in solid form, and distilling; the distillate caught at 293°, is the new compound. It is also obtained by distilling chloride, *b.*, with fuming sulphuric acid, catching that which follows the dry sulphuric acid. It is a colorless, oily liquid, fuming in the air, boiling at 293°.

e. Iodide of sulphur is obtained by heating the two elements together.

Bisulphate of iodide is formed by distilling a mixture of dry sulphite of lead and iodine.

The above two bisulphates are regarded by some as sulphuric acid, in which 1 eq. oxygen is replaced by 1 eq. chlorine (or iodine), with the form. SO₂Cl; but the chlorine does not act the part of oxygen in the body, and moreover the pentasulphate cannot well be explained on the same principle.

f. Biammoniacal subchloride of sulphur. 2 NH₃ + S₂Cl. Made by gradually saturating sub-

chloride in an atmosphere of ammonia. A light yellow liquid of some permanency, and gradually decomposing in its aqueous, not in its alcoholic solution. By passing the subchloride into dilute and cooled ammonia, and washing with ice-water to extract salammoniac, a red mass is obtained, of the composition $\text{NH}_3, \text{SCL} + \text{NH}_3, \text{NS}_3$.

g. Sulphochloride-ammonia, NH_3, SCL . Made by passing ammonia-gas, in small quantities at a time, into chloride of sulphur fully saturated with chlorine; is a red, flocculent body, soluble in alcohol and ether. Heated to 212° it becomes yellow without change of weight, and is then $3 \text{NH}_4\text{Cl}$ and $\text{NS}_3 + \text{SCL}$. The latter absorbs ammonia-gas, becoming green and then blue.

h. Sulphochloride-biammonia, $2 \text{NH}_3, \text{SCL}$. Obtained by exposing *g.* to ammonia until saturated, or lemon-yellow; is a yellow powder, soluble in alcohol and ether, decomposed by water, leaving sulphuret of nitrogen, beginning to decompose between 113° and 122° , fully at 212° , evolving nitrogen and ammonia, and subliming sulphur, salammoniac, and sulphuret of nitrogen in fine crystals.

5. Sulphuret of nitrogen, NS_3 . Obtained by water or heat from the preceding *4. h.*; is a light green powder, soluble in and crystallizable from ether, decomposed readily by hot water into hyposulphite of ammonia with excess of acid; $2 \text{NS}_3 + 6 \text{HO} = 2 (\text{NH}_3, \text{S}_2\text{O}_2) + \text{S}_2\text{O}_2$. See CARBON and the several metals, for other compounds of sulphur.

SULPHUR. *Min.* Right rhombic, showing the 8-hedra, several rhombic prisms, and end-plane; also imitative, granular, and in concentrated layers. $\text{H.} = 1.5\text{--}2.5$. $\text{G.} = 2.072$. Yellow, also reddish, greenish, and brownish; lustre resinous; transparent, subtranslucent; sectile and brittle, with conchoidal fracture. It is sulphur, S , containing at times clay, bitumen, selenium, &c. It occurs near volcanoes, or in gypseous rocks. Sicily, Volcano, and Solfaterra, near Naples, afford the greater part of sulphur in commerce.

SULPHURET OF CADMIUM. See GREENOCKITE.

SULPHURETTED HYDROGEN, } See SUL-
SULPHURIC ACID, } PHUR.

SULPHATES.

SULPHURIC ETHER. See ETHYL.

SULPHUROUS ACID. See SULPHUR.

SUMAC. The berries of the *Rhus glabrum* owe their acidity to bi-malate of lime, which may be removed by hot water. The bark and warty excrescences upon the leaves owe their efficacy, for tanning purposes, to a large content of tannic acid. The powdered leaves, peduncles, and young branches are used in dyeing.

The English sumac is from the *Rhus coriaria*.

SUMBUL. The Persian musk root. Reinsch's analysis gives its composition as follows:—

Water 0-130
Essential oil.....traces.

Extracted with Ether.

Balsam 0-126
Wax..... 0-002

Extracted with Alcohol of 0-819 spec. grav.

Balsam 0-002

Aromatic resin..... 0-003
A bitter substance, soluble in water
and alcohol 0-010

Extracted with Alcohol of 0-933 spec. grav.

A bitter substance, soluble in water
with gelatin and vegetable salts 0-064
A yellow, bitter, coloring substance,
soluble in alcohol 0-040

Extracted with Water.

A gum soluble in cold water..... 0-082
Starch and salts..... 0-284
Gelatinous sediment..... 0-072

Fibre..... 0-076
Starch..... 0-100

(*Chem. Gaz.* i. 637.) 0-991

Balsam. Of the color and consistence of balsam copaiva. Has a burning, aromatic taste, and diffuses the odor of musk when in contact with water. Sulphuric acid dissolves it with a splendid blue color. Distilled with water, it yields essence; distilled alone, a yellow oil passes over, and subsequently a greenish one, and ultimately a dark blue one (*Jahrb. f. Prakt. Pharm.* vii. 79). When distilled with potassa solution it gives an oily liquid which, by treatment with sulphuric acid, yields *Sumbulolic acid*.

SUNSTONE. See FELDSPAR.

SUPER. A prefix applied to a higher oxide or an acid salt. Thus, for example, a super-salt or super-oxide contains a greater proportion of acid or oxygen than a neutral salt or protoxide. Conversely, in a sub-salt or sub-oxide, the ratio is less.

SWAGA. It is BORAX.

SWEAT. See PERSPIRATION.

SWEET-BAY. See LAURUS NOBILIS.

SWINESTONE. See CALCAREOUS SPAR.

SYENITE. See SIENITE.

SYLVIC ACID. See COLOPHONY and ROSIN.

SYLVINS' SALT. Chloride of POTASSIUM.

SYMBOLS. *Chem.* The initial letters of the Latin names of the elements, sometimes associated with a small letter of the same name, as N, Nitrogen; Na, (Natrium) Sodium. The combination of these constitutes a FORMULA, and figures annexed express the number of equivalents. Some organic compounds acting like simpler inorganic bodies, are sometimes represented by symbols, as Cy, Cyanogen; or with a dash over it, for acids, as $\bar{\text{A}}$, Acetic acid; or with a cross, for alkaloids, as M^+ , Morphia. See EQUIVALENTS.

SYMPLESITE. *Min.* Cryst. Oblique rhombic. $\text{H.} = 2.5$. $\text{G.} = 2.957$. Color indigo, green; pearly; subtransparent, translucent. In a tube it yields 25 pr. ct. water, and becomes brown; on coal it yields the odor of arsenic, becomes black and magnetic without fusion. It is probably arseniate of iron. From Lobenstein, Voigtland.

SYNAPTASE. See EMULSIN.

SYNOVIA. The viscous fluid exhaled by the synovial membranes surrounding the movable articulations, and serving to lubricate the joints. According to John's analysis, it contains,—

Water	92.80
Albumen.....	6.40
Extractive matter (with NaCl and NaO, CO ₂).....	0.60
Phosphate of lime.....	0.15

SYNTHESIS. *Chem.* From *Synthesis*, composition. That branch of chemistry by which elements or compounds are made to unite definitely together, to produce new bodies. Thus, for example, the union of oxygen and a metal as oxide, or of an oxide with an acid, to form a salt. Synthesis is in contradistinction to ANALYSIS, the results of which it is sometimes employed to verify; thus, the composition of water having been determined by analysis to consist of two volumes of hydrogen and one of oxygen, the union of these two in the same proportions will produce water, without a remainder of either.

T.

TABULAR SPAR. *Min.* Table spar; Gram-mite; Wollastonite; *Ger.* Schaalstein, Tafelspath.

Cryst. Triclinic, prismatic, with one perfect cleavage; also fibrous. *H.* = 4–5. *G.* = 2.78–2.9. White, sometimes tinted; vitreous; translucent; brittle. It fuses imperfectly to a bead, is soluble in borax and mic. salt, leaving silica in the latter; fuses with a little soda to a blebby glass, and with more soda is infusible. Perfectly decomposed by muriatic acid, gelatinizing. Form. 3 CaO, 2 SiO₃. It occurs in many localities, of which those on the border of Lake Champlain are the most abundant. Both at these localities and in Sweden it is associated with colophonite and coccolite.

TACHYLITE. *Min.* A velvet-brown, or black mineral, not crystallized, from the basalt of Saesbühl. It contains SiO₃, AlO₃, FeO, MgO, CaO, NaO, KO, TiO₂.

TAKAMAHAKA. *Syn.* Tacamahac. The resinous exudation from the *Fagara octandra*. In bright yellow or dark brown, dusty pieces, of irregular form, agreeable odor, and bitter balsamic taste. It consists of resin and oil, and is soluble in alcohol, ether and the alkalies. There are several varieties of this resin, but none have been fully examined.

TALC. *Min.* *Cryst.* Right Rhombic, with one perfect cleavage; also granular, compact. *H.* = 1–1.5. *G.* = 2.697–2.85. Prevailing color, pale apple-green, also white, and dark green; lustre pearly; translucent; greasy touch; very sectile; thin laminae, flexible, not elastic. By ignition it becomes highly luminous, exfoliates and does not fuse; soluble in borax and mic. salt, leaving silica in the latter; swells up with soda and forms a slag; gives a reddish tint with cobalt solution; not attacked by sulphuric or muriatic acid, either before or after ignition. The formula is still doubtful, it appearing to vary from MgO, SiO₃ to 3 MgO, 2 SiO₃; the proportion 6 MgO, 5 SiO₃ seems to be most frequently obtained. It is most probably MgO, SiO₃ with variable quantities of 3 MgO, 2 SiO₃, having been subject to pseudomorphic action. It often occurs in large beds associated with talcose slate, serpentine and gneiss.

TALCAPATITE. *Min.* A mineral from Slatoust, in the Ural, described by Hermann, who gives the form. 3 MgO, PO₅ + 3 (3 CaO, PO₅) (?).

TALCITE. See NACRITE.

TALCOSE SLATE. *Geol.* A primary rock, of slaty structure and soapy feeling, generally supposed to contain talc instead of mica. But some late examinations of talcose slate from St. Gotthardt and Zillerthal give no magnesia, and indicate only mica.

TALLOW. *Chem. Tech.* *Syn.* Beef suet. This term is almost exclusively applied to that kind of Fat taken from beeves, though sometimes also extended to mutton-suet, deer and goat fat. Chemically considered, it is, when “rendered,” a mixture of OLEIN, MARGARIN and STEARIN, the latter component predominating. Those which have any peculiar odor contain also some volatile fat, to which it is owing. The principal applications of tallow are in the manufacture of soaps and candles, and the greater its solidity the more applicable for these purposes. Its firmness varies with the part from which it is taken as well as with the nature of the animal’s food; thus, for example, hard tallow, like that from Russia, is “fodder fed,” and far more valuable than that which has been “still” (grains) or mast fed. Moreover, the tallow from the vicinity of the caul, heart, kidneys, and intestines is firmer and superior to that from other parts of the animal.

Tallow, as taken from the animal, is what is technically termed “rough,” that is, in its natural envelope of cellular tissue and membranous casings. The process of freeing it from these foreign matters is termed “rendering” or “clarifying;” and is done by mincing the rough tallow and heating it during constant stirring in an open pan. The heat must be gentle and uniform, and continued until the expulsion of all water, which may be known by the liquid fat, at first milky, becoming clear. At this stage the membranous portion will be hard, and will cease to yield any more fat. The contents of the pan while still liquid must be strained into barrels or pans. The residue remaining upon the strainer must be reheated and subjected to pressure, as directed at p. 523 fig. 43. The exhausted cake is called “cracklings,” and makes excellent material for the manufacture of prussiate of potassa or for artificial manures. Beef tallow yields 95 and mutton suet 91 pr. ct. of clarified product.

There are many disadvantages in this mode of rendering; the principal of which are 1st, the loss in the large proportion of residue, (owing to the imperfect manner of heating, which prevents the extraction of the whole of the fat), and 2d, the noxious and inflammable gases evolved during the process. It has been sought to obviate these by the direct application of steam, and Wilson’s tanks have partially accomplished the objects, but as a portion of the gelatin is dissolved during the process and will remain with the tallow to deteriorate it in time by imparting a bad odor, some more effectual means are desirable.

D’Arcet’s method, said to be excellent, is to mix the minced tallow with one half its weight of water acidulated with 3.3 pr. ct. sulphuric

acid, and to continue boiling until the complete separation of the fatty from the cellular matter. If the steam is applied directly, the water may be diminished to a 5th and the acid increased to 6 pr. ct. This mode yields 2 to 5 pr. ct. more tallow than the old plan of rendering; for by chemically destroying the cellular matter, it renders easy the entire separation of the fat, and moreover prevents or greatly modifies the stinking vapors, and hardens and improves the quality of the tallow.

There are several other modes of rendering tallow and hardening it by admixture with certain salts, all of which are detailed in Morfit's "*Applied Chemistry*."

TAMARINDS. The fruit of the *Tamarindus Indicus*, containing in 100 parts, citric acid 9.40, tartaric acid 1.55, malic acid .45, bitartrate of potassa 3.25, gum 4.70, jelly 6.25, parenchymatous matter 34.35, and water 27.55.

The pods are preserved by saturating them with boiling syrup, and thus prepared are exported from the West Indies, the source whence we obtain them.

TANGHININ. *Chem.* Syn. Tanguin. Extracted by ether from the seeds of the *Tanghinia Madagascariensis*, after the separation of the oil by pressure. Crystallizes in brilliant scales, which are poisonous. Effloresces on exposure, and dissolves in alcohol and ether, and in water imparting a bitter, acid taste.

TANGUE. *Agric.* The sand, lining the sea shore, containing the organic matter thrown up by the surf. It is used as a manure, but should, for the purpose, be previously washed free of salt. *Dead tangle* is that which has lost strength by the putrefaction of its animal matter.

TANKELITE. *Min.* Xenotime, Phosphate of Yttria. Cryst. Quadratic, with perfect lateral cleavage. $H. = 4.5-5.0$. $G. = 4.14-4.56$. Yellowish brown, resinous, opaque; fracture splintery, uneven, with pale, brown streak. Behaves like apatite, but is infusible; with boracic acid and iron it shows phosphoric acid; insoluble in acids. From Lindesnaes, Norway.

TANNIC ACID. } *Chem.* Syn. Tannic acid.

Quercitannic acid exists most abundantly in GALL NUTS, but is also found in the bark of every species of *Quercus* and in numberless other plants, save in the leaves of herbaceæ, which, with few exceptions rarely contain it. The tannin of nut-galls serves as the type of all other species, and gives a bluish black precipitate with persalts of iron, while that from certain other sources gives a green or a gray reaction; and hence the names of green and gray applied to such tannins.

Prep. Dormine prepares tannin economically by macerating powdered galls, which have been exposed for several days to a moist atmosphere, with ether of .76 spec. grav. sufficient to form a thin paste. In a day or two the vessel is to be unclosed, and its contents transferred to a square piece of duck linen, and subjected to gradual pressure. The syrupy liquid running off is to be exposed in very thin strata to a heat of 104° to 113° . The evaporation of the ether in this way leaves the tannin

in light porous laminae. In order to entirely exhaust the galls, the pressed caked should be powdered and macerated, and pressed twice, each time with ether, as above, to which 6 pr. ct. of water is added. This method yields 75 pr. ct. of tannin. To remove chlorophyll oil, gallic and ellagic acids, it must be well washed with a mixture of ether and water. After frequent agitation and subsequent repose, three strata are formed, of which the lower is pure tannin.

As it is desirable sometimes to estimate the tannin value of a material to be used for the operation of tanning, Warrington has invented a process which consists in employing a test liquor of gelatin of such strength that each measure of 10 grs. in the ordinary alkalimetry tube, having the volume of 1000 grs. of distilled water divided into 100 equal parts, shall be capable of precipitating the tenth of a grain of pure tannin. A hot infusion of the material to be examined, in a bruised state if necessary, is to be prepared, strained, and the test gelatin liquor gradually added until no further precipitate is formed. To obtain at intervals portions of the solution under trial in a bright state, so as to be able to ascertain the progress of the operation, a glass tube having an internal diameter of about half an inch is employed, having the lower orifice loosely closed by a small piece of wet sponge; this, from the curdy nature of the precipitate, on being immersed, allows the clear liquor to filter through the sponge by ascent, and the filtrate is then to be poured into a small test-glass, and acted upon by an additional quantity of the solution of gelatin; if this renders it turbid, it is decanted back to the original bulk, and the process continued. In this way great accuracy may be arrived at after a little practice. (*Ch. Gaz.* v. 147.)

Prop. Form. $C_{15}O_5O_9 + 3 H_2O$. Has a pale yellow color and shining appearance: and forms an astringent solution with water, from which sulphuric, hydrochloric, phosphoric, arsenic and boracic acids precipitate it as a white compound of tannin and the other acids, soluble in pure water and in alcohol. The sulphuric compound by boiling in dilute oil of vitriol or caustic alkali yields a large amount of crystallized gallic acid.

Tannin precipitates solutions of starch, albumen and gluten. Its compound with gelatin is known in the arts as leather, and hence its use in tanning skins.

By exposure to air, or by the aid of ferments, the aqueous solution of tannin is transformed into gallic and ellagic acids. By adding potassa in excess to the solution, previous to exposing it, the *tannoxylic* or rubitannic acid is formed. Its formula in the anhydrous state is $C_{15}H_5O_{11}$, and that of its lead salt is $3 PbO, C_{15}H_5O_{11}$. By boiling instead of exposing the potassic solution of tannin, *tannomelanic* or *tannohumic* acid is formed. It is a dark humus-like powder, of the composition $C_{14}H_5O_7, 2 H_2O$, and is bibasic. *Buchner, jr.*

When heated in open vessels, tannin burns without residue, but by distillation yields the same products as GALLIC ACID.

According to Wöhler and Frerichs, tannin, in its passage through the animal system, is trans-

TANSY.

formed into gallic and pyrogallic acids, and humus-like substances.

Tannate of Potassa. $2\text{KO}, 3(\text{C}_{18}\text{H}_8\text{O}_{12})$ prepared by gradually neutralizing tannic acid with potassa. White flocculæ are formed which slowly turn to gray, then green, and finally become crystalline. The excess of tannin which should always be used may be removed by alcohol.

Tannate of Ammonia. $\text{NH}_3, \text{HO}, \text{C}_{18}\text{H}_8\text{O}_{12}, \text{C}_{18}\text{H}_5\text{O}_9$. Obtained as white flocculæ by passing ammoniacal gas through a solution of tannin in absolute alcohol.

Tannates of Baryta. The salt obtained by the double decomposition of chloride of barium and tannate of soda contains $4(\text{C}_{18}\text{H}_8\text{O}_{12}), 3\text{BaO}$; and that precipitated by absolute alcohol and carbonate of baryta from concentrated aqueous solution has the composition $3(\text{C}_{18}\text{H}_8\text{O}_{12}), 4\text{BaO}$. The persalts of iron strike a blue-black color with the neutral tannates. Those tannins which precipitate the persalts of iron, gray or green, are either principles peculiar to the plant whence obtained, or else are true tannin, which varies from its characteristic reaction owing to combination with some foreign matter. Stenhouse classifies the tannins into those which do, and those which do not yield pyrogallic acid.

TANSY. The herb *Tanacetum vulgare*. It contains, according to Fromherz and Peschier, wax, chlorophyll, yellow coloring matter, tannic and gallic acids, bitter extractive, gum, woody fibre, and

Volatile oil. Yellow, sometimes green; of a bitter taste and spec. grav. 952. Bitter extractive, or extractive consisting partly of resin.

Tanacetic acid. Crystallizable, and precipitates lime, baryta, and oxide of lead. Leroy also found a peculiar inodorous and bitter substance, very soluble in ether, less so in alcohol, and almost insoluble in water, imparting to it however a bitter taste, which he called *Tanacetin*.

TANTALITE. *Min.* See COLUMBITE. It may be added that the spec. grav. varies from 5.47 to 7.48.

TANTALUM. See COLUMBIUM.

TAPIOCA. *Pharm.* The granular fecula of the root of the Cassava (*Jatropha Manihot*) plant. Prepared as meal, it is called *Moussache* or *Cipipa* (Brazilian arrow-root). It is highly nutritious, and forms an excellent article of diet for the sick, and for this purpose is to be boiled in water and seasoned with lemon juice and sugar. The "pearl tapioca" sold in the shops is a factitious article made probably from potato starch.

TAQUA NUT. *Syn.* Vegetable Ivory. The fruit of the *Phytalephas macrocarpa*, a South American plant allied to the palms. Connel's analysis gave; gum 6.73, legumin 3.80, albumen .42, fat oil 0.73, ash 0.61, water 9.37, lignin 81.34.

Mulder expresses its composition by $\text{C}_{24}\text{H}_{12}\text{O}_{11}$.

TAR. *Syn.* Pix liquida. The dark viscid liquid obtained in the distillation of wood, and consisting of pyrogenous resin dissolved in volatile oils and acetic acid. These latter being evaporated, the tar hardens into PITCH.

TARTARIC ACID.

The oil of tar obtained by distillation consists of essence of terpentine, owing its dark color to the presence of pyrogenous oil and resin. PARAFFIN, EUPHORE, CREASOTE, PICAMAR, CAPNOMOR, and PITTACAL, and Pyroligneous acid are also products of the distillation of tar.

TARAXACUM. *Syn.* Dandelion. The root of the *Leontodon taraxacum*. The juice contains, according to John and Squire, resin, sugar, gum, inulin, salts of potassa and lime, albumen, gluten, water, and a peculiar principle, the

Taraxacin of Pollex. Crystallizable, bitter, fusible but not volatile, sparingly soluble in cold, very soluble in hot water, in alcohol, and ether.

TARTAR.

TARTAR EMETIC. } See TARTARIC ACID.

TARTARIC ACID. *Chem.* Found by Scheele originally in grape juice, but existing also in madder, potatoes, quassia, squills, and numerous other plants.

Prep. One part of crude tartar (ARGAL), in powder, is boiled for two or three hours in water sufficient to dissolve it. The crystals which form on cooling are to be redissolved in water, treated with 4 pr. ct. of bone-black and pipe-clay, filtered, and set aside to recrystallize. In this way tartrate of lime, lees, coloring, and other foreign matters are separated. To these purified crystals dissolved in 10 pts. of water, powdered chalk is to be added until effervescence ceases. Insoluble tartrate of lime and soluble (neutral) tartrate of potassa are formed. To convert the latter into the former, sulphuric acid must be added. Sulphate of lime is thus formed in proportion sufficient for the precipitation of the neutral tartrate of potassa, as tartrate of lime. Filter, wash, and treat the precipitate with dilute sulphuric acid, which eliminates the acid, and forms insoluble plaster of Paris. The filtered liquor, on evaporation, will yield tartaric acid, which requires several crystallizations for its purification.

Prop. $\text{C}_8\text{H}_4\text{O}_{10}, 2\text{Aq}$ crystallized, or it may be written $\text{C}_4\text{H}_2\text{O}_5, \text{HO}$. Crystallizes in colorless, transparent, oblique rhombic prisms, of an agreeable sour taste, and spec. grav. 1.75. Is unalterable in the air, soluble in alcohol, and readily in water. Its aqueous solution moulds on exposure, and yields acetic and butyric acid. It combines and forms salts with all the oxides; but caustic alkalies in excess and at high temperatures produce its decomposition into acetic and oxalic acids.

Action of Heat. According to Laurent and Gerhardt (*Comptes Rendus*, 1848), tartaric acid may become modified without loss or any change in composition. By fusion merely, it is modified into a mixture of two acids isomeric with the original acid, metatartaric and isotartaric.

Metatartaric acid. Forms crystallizable salts, distinguishable from the corresponding tartrates by their greater solubility. The bi-salts of ammonia, $\text{C}_4\text{H}_5\text{AmO}_6$, and the neutral salts of lime, $\text{C}_4\text{H}_4\text{Ca}_2\text{O}_6 + 3\text{Aq}$, are especially characteristic in this respect. This acid and its salts are converted into tartaric acid and tartrates, by ebullition.

Isotartaric acid. Its neutral salts have the composition of the bi-tartrates, and hence in

TARTARIC ACID.

the modification, tartaric acid has solely, by a molecular transposition, changed its capacity of saturation. The neutral isotartrate of lime, $C_4H_5CaO_6$, extremely soluble and uncrystallizable, if heated, alters into neutral, crystallizable metatartrate of lime, and metatartaric acid.

Tartrellic acid. $C_4H_4O_5$. Obtained by heating tartaric acid until water ceases to be given off. Is deliquescent, soluble in water, and furnishes salts of the formula of the bitartrates, minus 1 eq. of water. The tartrellic acid of Fremy is a derivative of *tartralic* acid, which he obtained by heating tartaric acid.

By a still higher heat tartaric acid may be converted into an oily and a crystalline pyrogenous acid.

According to Laurent and Gerhardt, the so-called insoluble, anhydrous acid, which Fremy obtained by heating tartrellic acid, is only an isomorphous condition of the original acid.

Action of Ammonia. When ammoniacal gas is passed over anhydrous tartaric acid, moistened with alcohol,

Tartrate of ammonia is formed. It is insoluble in alcohol, but dissolves readily in water. (*Laurent, Ann. der Chem. und Pharm.* lx. p. 326.)

Action of Acids. Oil of vitriol abstracts water from tartaric acid, and gives products analogous to the tartralic and tartrellic acids of Fremy. Under certain circumstances of

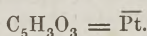
TARTARIC ACID.

time and temperature, it forms sulphotartaric acid, or disengages carbonic oxide and sulphurous acid, leaving a black, undetermined residue. Nitric acid oxidizes and transforms tartaric into oxalic acid.

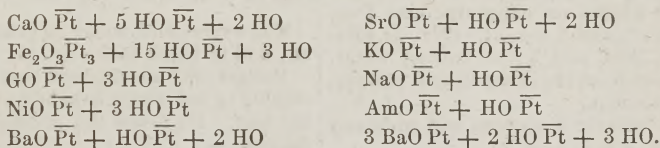
Action of Sugar. Tartaric acid, according to Vogel, when mixed with three parts of sugar and exposed to moist air, attracts moisture, and forms with absolute alcohol a solution from which lime precipitates only traces of tartrate. Neither the sugar nor tartaric acid can be separated from the alcoholic or the aqueous solution, in crystals. The modification thus produced is Fremy's *tartralic* acid (*Chem. Gaz.* iv. 150).

Pyrotartaric acid. $C_5H_4O_4$ (*Arppe*). Prepared by distilling RACEMIC or tartaric acids, the former with pumice-stone, and the latter with platinum-black (*Millon and Reiset*). Crystallizes in discoid groups of long, transparent prisms. Is soluble in water, alcohol and ether; melts at 212° , and boils at 374° . The formula of its silver salt is $AgO, C_5H_3O_3$.

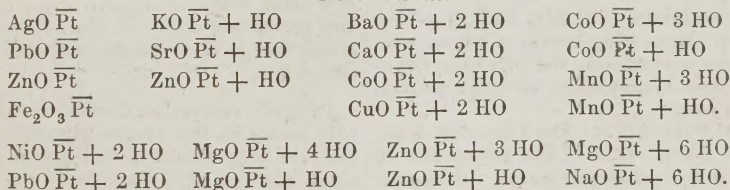
Pyrotartaric acid, when distilled with fused phosphoric acid, yields anhydrous acid, $C_5H_3O_3$, a colorless, oily liquid, boiling at 446° , and remaining liquid at 14° . From its alcoholic solution water throws down oily drops, which after a time crystallize. Below is Arppe's tabular arrangement of the formula of the pyrotartrates:—



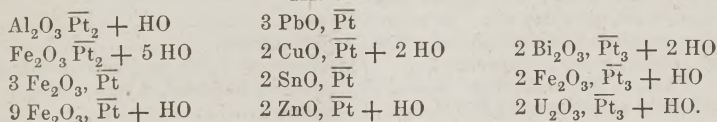
I. Acid Salts.



II. Neutral Salts.



III. Basic Salts.



(*Liebig's Annalen*, lxxvi. 73, and *Chem. Gaz.* vi. 313.)

TARTRATES.

The neutral salts have the formula $2 RO, \overline{T}$, and the acid salts $RO, HO, \overline{T}$. All of the tartrates emit the odor of caramel, when heated above 392° . The soluble neutral salts become less so upon the addition of an excess of the acid; this addition dissolves those which are insoluble or only sparingly soluble. The tartrates insoluble in water, are distinguished by their ready solubility in aqua ammonia and caustic potassa.

Tartrate of Potassa (neutral). $2 KO, HO, C_5H_4O_{10}$. Prepared by neutralizing cream of tartar with carbonate of potassa. Crystallizes in right rhombic prisms, which are very soluble in water.

Bi-tartrate of Potassa. Syn. Cream of tartar, Supertartrate of potassa. $KO, HO, \overline{T}$. Drops as crude tartar or argol from sour wines, and purified as directed for the preparation of tartaric acid. Crystallizes in hard, opaque, oblique rhombic, or irregular six-sided prisms. They

are slightly acid to the taste and to test-paper, unalterable in the air, but fusible and decomposable by heat into carbon and carbonate. Is soluble in 18 pts. hot and 200 pts. of cold water, in the strong mineral acids, in caustic and carbonated soda and potassa, but insoluble in alcohol.

Tartrate of Oxide of Ethyl. Syn. Tartrovinic acid. $\text{AeO}, \text{HO}, \bar{\text{T}}$ (*Guérin Varry*). Crystallizes in long, rhombic prisms, very soluble in water and alcohol, but insoluble in ether. It forms double salts with the bases.

Soluble Tartar. Syn. Tartrate of potassa and boracic acid. $\text{KO}, \bar{\text{T}}, \text{BO}_3$ (*Duflos*). Prepared by heating together $47\frac{1}{2}$ pts. of cream of tartar and $15\frac{1}{2}$ pts. of boracic acid with water, and evaporating the solution. Forms a white, amorphous acid mass, very soluble in water, but insoluble in alcohol.

Seignette's Salt. Syn. Tartrate of soda and potassa, Rochelle salt. $\text{C}_8\text{H}_4\text{O}_{10}$, 2 HO (KO, NaO, 6 HO). Prepared by dissolving together in water 1 pt. of crystallized carbonate of soda and $1\frac{1}{2}$ pts. of cream of tartar. Crystallizes in large, transparent, right rhombic, 6, 8, and 10-sided prisms.

Tartar Emetic. Syn. Tartrate of antimony and potassa, Tartarized antimony. $\text{C}_8\text{H}_4\text{O}_{10}$, 2 HO, KO, Sb_2O_3 . Prepared by triturating together 3 pts. of oxide of antimony and 4 pts. of cream of tartar, thinning with water, and heating the mixture at 158° , until complete solution. Filter and evaporate, to form crystals. Forms octahedral crystals of great brilliancy. They whiten on exposure, lose 1 eq. of water at 212° , and 2 eqs. at 442° . Is soluble in 14 pts. cold, and 2 pts. boiling water, and precipitable from the latter in fine powder, by excess of alcohol.

The neutral tartrate of potassa and antimony consists of 3 $\bar{\text{T}}$, 3 KO, SbO_3 .

Ammoniated Tartar. Syn. Tartrate of potassa and ammonia. $\bar{\text{T}}, \text{KO}, \text{AdH}_2\text{O} + \text{Aq}$. Prepared by neutralizing cream of tartar with ammonia, and crystallizing the solution. Crystallizes in large, transparent, rhombic prisms, soluble in water.

TARTROVINIC ACID. See TARTARIC ACID.

TASTE. *Chem.* One of the properties of bodies which are soluble in water. It is pungent, like mustard; saline, like common salt, nitre, &c.; bitter, like aloes; astringent, like oak bark; sweet, acid, alkaline, &c. In mineralogy it is also employed to distinguish a few minerals: salt, trona, borax, copperas, &c.

TAURIN. *Chem.* Redtenbacher (*Liebig's Annalen*, 1848) gives as its formula $\text{C}_2\text{NH}_4\text{O}_6\text{S}_2$, equal to bisulphate of aldehyde-ammonia, in about the same state of condensation as cyanate of ammonia in urea. See BILE.

TAUTOLITE. *Min.* A mineral from Laacher lake, related to chrysolite, but not well examined.

TEA. The dried leaves of the *Thea Chinensis*, an evergreen plant, native to China and Japan. An aqueous decoction forms the well-known refreshing beverage. The different varieties of tea are all from the same species, though classified under the two grand divisions of *green* and *black* teas. Their difference exists in the mode of culture, preparation, and the

nature of the soil upon which grown, the latter having an important influence upon the aroma (due to essential oil), upon which its commercial value mainly depends.

Warington has shown (*Chem. Gaz.* ii. 196) that the difference in tint is owing to adventitious substances mechanically attached to the surface of the curled leaves. This pulverulent coating upon green tea was proved by chemical and microscopic investigation, to be Prussian blue and sulphate of lime, with traces of silica, alumina, (probably kaolin), and magnesia. It was also ascertained that the bloom and tint characteristic of teas is imparted by a mixture of gypsum and some appropriate vegetable color; hence the teas as they reach us are always adulterated.

The constituents of green tea are (according to Mulder), in 100 pts. :—

Volatile oil	0.79	Thein (CAFFEIN)..	0.43
Chlorophyll.....	2.22	Extractive, trace	
Wax	0.28	of apotheme	22.80
Resin.....	2.22	Muriatic extract	23.60
Gum	8.56	Albumen	3.00
Salts.....	5.56	Lignin	17.68
Tannin.....	17.80		

Black tea contains, in 100 pts. :—

Volatile oil	0.60	Tannin.....	12.88
Chlorophyll.....	1.84	Thein (CAFFEIN)..	0.46
Resin.....	3.64	Extractive	19.88
Gum.....	7.28	Apotheme	1.48
Albumen	2.80	Muriatic extract	19.12
Lignin	28.32	Salts.....	5.24

The average of water in green teas is 10 pr. ct., and in black teas 8 pr. ct.

Peligot has ascertained that the proportion soluble in hot water depends upon the age of the leaf. He found the average in 100 pts. as follows :—

	Soluble parts.
Dry black teas.....	43.2
Dry green teas	47.1
Black teas in their commercial state....	38.4
Green teas " " " "	43.4

Peligot's researches also prove that thein not only exists in far larger quantities than has hitherto been admitted, but that it is the principal nitrogenous substance. This chemist obtained from 100 pts. of—

	Thein.
Hyson.....	2.40
Another kind	2.56
Mixture of equal proportions of gun- powder, imperial, hyson, caper, and pekoe	2.70
Gunpowder.....	6.22
Another kind	3.50

(*Comptes Rendus*, 1843.)

TEARS. The limpid fluid secreted by the lachrymal glands. Their composition has not been accurately determined.

TEETH. Consist of three portions, the osseous part, or *dentine*; the enamel, or superior covering of the bony substance; and the cortical matter, overlaying the enamel of the crown.

The following is Von Bibra's analyses of human teeth :—

TELLURIC BISMUTH.

TELLURIUM.

	Molar tooth of a woman aged 25 years.		Molar tooth of an adult man.	
	Enamel.	Osseous portion.	Enamel.	Osseous portion.
Phosphate of lime, with a little fluoride of calcium.....	81.63	67.54	89.82	66.72
Carbonate of lime	8.88	7.97	4.37	3.36
Phosphate of magnesia	2.55	2.49	1.34	1.08
Salts.....	0.97	1.00	0.88	0.83
Cartilage	5.97	20.42	3.39	27.61
Fat.....	a trace	0.58	0.20	0.40

(Simon's Chemistry of Man, p. 607.)

The pretended destructive action of sugar upon teeth, is denied by Marchand (*Chem. Gaz.* v. 312) and others. A practical refutation exists, also, in the health and beauty of the teeth of the plantation negroes, who are constantly chewing the sugar-cane.

Decayed teeth are repaired by plugs of gold, tin, and cement. The first is by far the more durable; the latter should never be used, particularly, as in the case of "Succedaneum," where they contain mercury, which produces salivation, and ultimately poisons the system. White gutta percha, precipitated from its alcoholic solution by ether, and softened under water, makes a very excellent temporary plug.

Of the cements, that known as Dr. Ostermeyer's, is one of the least objectionable. It is made by *quickly* mixing together 13 pts. pure and finely powdered caustic lime, and 12 pts. anhydrous phosphoric acid, and *immediately* compressing a *g. s.* into the dried cavity of the tooth. In a short time it becomes very hard and firm, from the formation of phosphate of lime, and the tooth is thus rendered solid and serviceable. Asbestos, saturated with a solution of West India copal in absolute alcohol, and tinctured with oil of peppermint, is sometimes used as a temporary cement. The hollow of the tooth should be moistened with a tincture of guaiacum and myrrh, previous to its application.

Finely divided asbestos, immersed in "collodion" or ethereal solution of gun cotton, slightly narcotized with morphia, has recently been recommended as an effectual remedy for toothache.

TELLURIC BISMUTH. *Min.* Tetradyomite, Bornite. Cryst. Hexagonal, foliated. $H. = 2$. $G. = 7.5$. Lead-gray, steel-gray; metallic shining; opaque; sectile, soils paper slightly; foliæ not elastic. Fuses readily on charcoal, tinging the flame blue, forms a white coating with reddish border; in an open tube it fuses, gives the odor and a red sublimate of selenium, emits white fumes, and a yellowish white sublimate of tellurous acid, and leaves a brownish white residue. Form. $BiTe_3$, in which a portion of Te is replaced by sulphur in the Hungarian tetradyomite, and by selenium in the Virginian mineral. Occurs at Schemnitz, Retzbanya; Virginia, U. S.

TELLURIC LEAD. See FOLIATED TELLURIUM. Another species is described by G. Rose, with three rectangular cleavages. $H. = 3$. $G. = 8.159$. Tin-white; metallic; sectile. Behavior similar to foliated tellurium, leaving silver instead of gold. Form. $PbTe$, with a little $AgTe$. From the Savodinsky mine, on the Altai Mountains.

TELLURIC SILVER. *Min.* In coarse-

grained masses. $H. = 2 - 2.5$. $G. = 8.31 - 8.33$. Lead-gray, steel-gray; metallic. It fuses in an open tube, and gives a slight sublimate; it does not coat charcoal, and leave a brittle silver-globule. Form. $AgTe$. From the Savodinsky mine, on the Altai Mountains.

TELLURIUM. *Min. Ger.* Gediegen Sylvan, and Tellur. Cryst. six-sided prisms; also massive and granular. $H. = 2 - 2.5$. $G. = 5.7 - 6.1$. Tin-white; metallic; brittle. Fuses and volatilizes on coal, with much smoke and a greenish flame, leaving oxide of iron; in a tube it behaves similarly, and gives a sublimate, which fuses to clear drops of tellurous acid. Form. Te , containing some iron and gold. Talathna, Transylvania.

TELLURIUM. *Chem.* Sylvan, Tellur. Its existence was surmised by Müller v. Reichenstein in 1782, and proved by Klaproth in 1798, but nearly all its properties and combinations were investigated by Berzelius. It is among the rarest elements, occurring in native tellurium, telluric bismuth, foliated tellurium, graphic tellurium, &c.

1. *Prep.* From telluric bismuth, by mixing the powdered ore with an equal weight of carbonate of soda or potassa, and a little olive oil to make a stiff dough, heating it first carefully in a well-covered platinum crucible to char the oil, then to a white heat, pulverizing the mass rapidly, and washing it on a covered filter with boiled water, which dissolves chiefly telluret, seleniuret and sulphuret of alkali. By blowing air through the clear liquid, tellurium is precipitated; it is washed on a filter, collected, fused and distilled in a current of hydrogen to free it from impurities. From telluric silver it is obtained either by heating it in a stream of chlorine, or by heating it with 1 pt. nitre and $1\frac{1}{2}$ pts. carbonate of potassa, extracting with water, evaporating nearly to dryness, mixing with charcoal powder, drying thoroughly, and then treating it like telluric bismuth. Telluric gold is first boiled with muriatic acid several times and washed with boiling water to remove sulphurets, treated with nitric acid, the solution decanted from gold, evaporated to dryness, dissolved in muriatic acid and the tellurium precipitated by sulphurous acid or an alkaline bisulphite. When in solution it is separated from a large number of metals by sulphuretted hydrogen; from the precipitated sulphuret, tellurium, with antimony, arsenic, &c., is extracted by sulphhydrate of ammonium, and when in solution again as tellurous acid, is precipitated as metal by sulphurous acid or a sulphite. The separation of selenium and tellurium is best effected, converting them into seleniated and tellurated alkali, by fusion with carbonate of soda and nitre, (after previous

oxidation by nitric acid or aqua regia), dissolving in water, and adding nitric acid and nitrate of baryta. Seleniate of baryta remains undissolved.

Prop. When fused it is tin-white, metallic, lustrous, very brittle, spec. grav. 6.138—6.244; crystallizing in hexagonal or rhombic forms; when precipitated it is a brown powder; fuses below 600°, boils at a full red heat, giving a yellow vapor; above its fusing point it burns in the air with a blue flame to tellurous acid; oxidized to tellurous acid by nitric acid and hot oil of vitriol, to telluric acid by fusion with alkaline nitrate. Sym. Te. Eq. 64 (64.14. H = 1, or 801.76 O = 100. *Berz.*)

Tellurets. Tellurium and potassium, when heated, unite with a strong evolution of heat and light, forming a metallic, crystalline compound of a yellowish or reddish color, soluble in water with a purple color. The telluret of sodium is similar.

2. *Tellurous acid.* Oxide of Tellurium, TeO_2 . Made by evaporating the nitric solution of the metal to dryness, and gently heating; if evaporated spontaneously, it crystallizes; and still better by mixing a boiling solution of bichloride of tellurium in muriatic acid with boiling water and letting it cool, the acid separates in small 8-hedra. It becomes yellow by heating, and fusing at a beginning red-heat to a transparent yellow liquid, volatilizing slightly, congeals on cooling to a white crystalline mass. Its hydrate is made by precipitating an alkaline tellurite by nitric acid in very slight excess, stirring it for some time, and washing in a filter with ice-water. A white powder, reddening litmus, losing its water at 104°. The dry acid dissolves slightly in water, and the solution does not redden litmus; the hydrate is more soluble, the solution has acid reaction, decomposes at 104°, precipitating dry acid. The hydrate dissolves in acids as an oxide, forming salts, which have a similar taste and emetic effect with salts of antimonie oxide. Metallic tellurium is thrown down from their solutions by many of the metals, sulphurous acid and alkaline bisulphites, tin-salt and copperas; precipitates white by alkalis and their carbonates (soluble in excess of alkali), by phosphate of soda, acetate of lead, nitrate of mercurous oxide; blackish brown, by sulpho-hydrogen and sulphide of ammonium (soluble in excess of the latter); grayish blue by ammonia-oxide of copper; yellow by tincture of galls.

Tellurites. As an acid, it readily unites with the alkalis by fusion or in the wet way; other salts are obtained by precipitation with the alkaline, or by fusing the acid and oxide together. An oxide unites with 1, 2 or 4 of the acid. The salts are colorless, if the base be so; fusible, congealing crystalline; generally reducible by ignition with charcoal to metallic tellurets; the alkaline are readily soluble in water; the alkaline-earthly, difficultly; the rest insoluble; nearly all are soluble in strong muriatic acid, and the solutions give the reactions of oxide of tellurium, unless a strong base interfere.

3. *Telluric acid.* TeO_3 . Obtained by dissolving tellurous acid in twice as much potassa lye as is necessary for saturation, passing chlorine through the liquid until the precipitate re-dis-

solves and it smells of chlorine, supersaturating with ammonia and adding a solution of chloride of barium, as long as a precipitate ensues, washing the latter with ice-water, drying it at a gentle warmth, decomposing 1 pt. of this tellurate of baryta by 1 pt. oil of vitriol with 4—8 pts. water, and evaporating the solution to crystallize, first in a water-bath, and then spontaneously. It is less completely changed into telluric acid by fusion at low redness with nitre. It forms large colorless crystals, without an acid, but a metallic taste; form. $\text{TeO}_3 + 3 \text{HO}$; they retain their water at 212°, lose 2 eqs. water at 320°, the 3d eq. below redness, leaving the dry acid, and at a still higher heat lose oxygen, becoming tellurous acid. The dry acid is insoluble in water, the hydrate and crystallized are slowly but quite soluble, the latter dissolving in every proportion in boiling water.

Tellurates. It is a very feeble acid, and the hydrate only drives out so much alkali from the carbonates that a bi-tellurate is formed. It unites with $\frac{1}{3}$, $\frac{2}{3}$, 1, 2 and 4 pts. base. The alkaline salts are soluble in water, the quadrisalts least; those of the alkaline-earths are less soluble, of the metals proper still less or not at all; the soluble salts give a white precipitate with chloride of barium, soluble in muriatic and nitric acids; they are easily reduced to tellurites by heat, and to tellurets by heating with charcoal. *Berzelius* assumes two modifications of telluric acid, the anhydrous and that in the hydrate. When 4 eq. of the hydrated acid are dissolved with 1 eq. carbonate of potassa in boiling water, and cooled slowly, the quadritellurate crystallizes out white, with the form. $\text{KO}, 4 \text{TeO}_3 + 4 \text{HO}$. If this salt be gently ignited, it forms a yellow powder, containing the insoluble modification, and the powder itself is insoluble in the cold in water, sulphuric, muriatic, and nitric acids, and in potassa lye; soluble in boiling nitric acid, and in fusing potassa, which changes the acid into the soluble modification. Quadritellurates of soda act similarly.

4. *Telluretted hydrogen.* Tellurhydric acid. HTe . Obtained by the action of muriatic acid on telluret of potassium, zinc or iron, is a colorless gas, smelling like sulphuretted hydrogen, soluble in water, which decomposes it, precipitating tellurium.

5. *Sulphur. a.* Bi-sulphuret, TeS_2 , obtained brownish black by passing sulphohydrogen through the solution of a tellurite, or by exposing a solution of an alkaline bi-sulphuret to the air as a shining black, half-metallic crust. It swells up by heat, half fusing, and is soluble in caustic alkali. *Sulphotellurites.* It forms salts with other sulphides, whose general formula is $3 \text{MS}, \text{TeS}_2$. Those of the alkalis are obtained by passing sulphohydrogen through a solution of their tellurites; the alkaline-earthly salts are made by boiling solutions of their sulphurets with bisulphuret of tellurium. The alkaline salts are brownish yellow when dry, pale yellow in crystals or in solution; they are soluble in water and decompose by exposure; the dry salts keep for some time. The salts of the metals proper are obtained by double decomposition; they are generally brown while moist, black when dry. *b.* Ter-

sulphuret. TeS_3 . Obtained by passing sulpho-hydrogen through a solution of telluric acid, is blackish gray, metallic, and forms sulpho-tellurates, which have not been minutely studied.

6. *Chlorine*. *a. Protochloride*, TeCl , obtained by passing a gentle stream of chlorine over tellurium or its dry acids, at a high heat, is black, fusible, volatile, with a vapor resembling the violet of iodine in color, decomposed by water into tellurous acid and tellurium; it combines with salammoniac. *b. Bichloride*, TeCl_2 , obtained by passing chlorine in excess over heated tellurium, until the black liquid becomes dark red and finally yellow; on congealing, it forms a white crystalline mass, which is fusible, and may be sublimed, is deliquescent and gradually decomposes with water, or in its muriatic solution, forming *tellurite of bichloride*; the latter is crystallizable and decomposable by water into a solution of chloride and a sediment of tellurous acid. Bichloride of tellurium and potassium is obtained by dissolving chloride of potassium in a muriatic solution of tellurous acid and letting it stand; chloride of potassium first separates, and lastly, yellow crystals of the new compound. The corresponding ammonium salt is made direct, and forms yellow crystals.

7. *Bromide* is made by distilling a mixture of the two elements with excess of bromine; a violet vapor condensing in black crystals. The *bibromide*, TeBr_2 , is made by adding powdered tellurium to bromine in a tube surrounded by ice, and evaporating off the excess of bromine. A red, fusible mass, which congeals crystalline, and sublimes in yellow vapor, condensable to yellow crystals; it dissolves in a little water, from which it may again be crystallized. Its salt with chloride of potassium is similarly made to the chloride-compound.

8. *Iodide*, TeI , is made by distilling a mixture of 1 eq. Te with a little more than 1 eq. iodine, and sublimes in black, metallic crystals. *Biniodide*, TeI_2 , made by digesting hydrate of telluric oxide with iodo-hydric acid, is black, crystalline, fusible with decomposition, decomposed slowly by cold water, readily by hot, which leaves tellurite of biniodide of tellurium. It also forms double salts with other iodides, and with hydriodic acid.

9. *Fluoride* is obtained by subliming the following body, tellurite of bifluoride of tellurium. The latter is made by dissolving tellurous in fluohydric acid and evaporating. After subliming the fluoride, the residue is a tellurite-fluoride, richer in tellurous acid.

TELLUROUS ACID. *Min.* Found in a thin coating on native Tellurium.

TENANTITE. *Min.* Graukupfererz. Cryst. Regular, 12-hedron with cube, $\frac{3}{8}$ -hedron and $\frac{3}{4}$ -hedron. $H. = 3.5-4$. $G. = 4.375-4.491$. Blackish lead-gray; metallic; fracture uneven, with reddish gray streak. On coal it emits arsenical fumes, and leaves a magnetic slag by fusion. Form. $\left. \begin{matrix} 4 \text{ Cu}_2\text{S} \\ 4 \text{ FeS} \end{matrix} \right\} \text{AsS}_3$, in which some of the sulphuret of iron is replaced by sulphuret of zinc. From the Cornish mines.

TEPHROITE. See MANGANOSILICATE.

TERBIUM. *Chem.* See YTTRIUM.

TEREBEN. See TERPENTINE and CAMPHEN.

TERENITE. *Min.* Cryst. Quadratic. $H. = 2$.

$G. = 2.53$. Yellowish white or green; pearly, feeble; brittle. It fuses in the outer flame to a white enamel, in the inner with intumescence to a blebby glass; gives a blue color with cobalt. From Antwerp, St. Lawrence Co. N. Y. *Emmons*.

TERPENTINE. Syn. Terebinthina. The resinous, semi-solid exudation of the whole genus of *Pinus* belonging to the *Coniferae* family. The Carolina or American terpentine is obtained from incisions made in the *Pinus palustris* and *tæda*. Venice terpentine is from the *Pinus larix*. By distillation with water essential oil passes over and resin remains. The different varieties are distinguished by their proportions of oil and resin.

Oil of terpentine. Syn. Terebenthene. Used in the arts as a solvent and as a thinner and drier of paints. The oil obtained at the first distillation contains resin, formic and other acids, from which it must be freed by distillation with water and subsequent rectification over chloride of calcium.

Prop. $\text{C}_{20}\text{H}_{16}$. A clear, colorless, very fluid essence, of strong balsamic odor, and sharp, biting taste. Spec. grav. 0.86 at 71.6. When pure, is neutral to test paper, boils at 312°, and gives a vapor of spec. grav. 4.764. Cooled to -16.6 it drops white crystals of hydrate. Is insoluble in water but dissolves readily in alcohol, ether, and the fat oils. Spirits of terpentine polarizes to the left, but this property is essentially modified by heat and other circumstances. See CAMPHEN.

Hydrate of Terpentine. Syn. Terpine, Terpentine, Camphor. Formula $\text{C}_{20}\text{H}_{22} + 6 \text{ aq.}$ (*Wiggers*) = $\text{C}_{20}\text{H}_{16} + 6 \text{ aq.}$

Drops spontaneously from the oil at very low temperatures or by long standing, and formed artificially according to Wiggers, (*Ch. Gaz.* iv. 364), by prolonged contact of the essence with nitric acid and alcohol. Crystallizes in right rhombic prisms, soluble in 200 parts of cold and 22 parts of boiling water, and more soluble in alcohol and ether. When heated to 217°, it melts and becomes anhydrous, $\text{C}_{20}\text{H}_{20}\text{O}_4$. This latter is a crystalline milky mass, which melts at 217°, boils at 489°, and sublimes when exposed to air into shining prisms.

Terpine, by the action of a few drops of the weakest acid upon its aqueous solution, and distillation is entirely transformed into—

Terpenole. $\text{C}_{28}\text{H}_{17}\text{O}$. A colorless, oily liquid, with the odor of hyacinths. Spec. grav. 0.852; boiling point 334°.

For the compounds of the above hydrates, with hydrochloric acid, see CAMPHEN. *Oxidation of the Oil*. By exposure to air, the oil resinifies and yields also formic acid. When heated with litharge, a new acid is formed, the

Térétinic acid. $\text{C}_9\text{H}_7\text{O}_5$. Separates from alcohol in delicate white crystals, and forms compounds with the metallic oxides.

By the prolonged action of nitric acid, the oil is converted into a nitrogenous resin, and *Terebenic acid*. Syn. Terpentinic or Terebic acid. $\text{C}_{14}\text{H}_9\text{O}_7$, HO, (*Bromeis*). Crystallizes in small, four-sided prisms, which are non-volatile. Rabourdin (*Chem. Gaz.* iii. 287) in a similar manner obtained *Terebic acid* identical in composition with the above, but differing in

properties. Is soluble in alcohol, hot water, and ether, and forms salts, which are nearly all soluble. The neutral lead salt, PbO , $\text{C}_{14}\text{H}_3\text{O}_7$, is in white crystals. The acid fuses at 392° , without loss of weight, but above that temperature decomposes into carbonic and *Pyroterebilic* acids. The latter, $\text{C}_{12}\text{H}_{10}\text{O}_4$, is a colorless, oily fluid, which retains liquidity to 4° . Is of a pungent taste, and caustic to the skin. Does not alter on exposure to air, dissolves in water, alcohol, and ether, and forms difficultly crystallizable salts of the composition RO , $\text{C}_{12}\text{H}_9\text{O}_3$.

In addition to the above named, prussic and oxalic acids and ammonia are among the products of the action of nitric acid upon oil of terpentine; and Cailliot (*Comptes Rendus*, xxiii. p. 920) has obtained three new acids, as follows:—

Terephthalic acid. $\text{C}_{16}\text{H}_8\text{O}_8 = \text{C}_6\text{H}_4\text{O}_6 + 2\text{HO}$. Is isomeric with Laurent's phthalic acid, from which, however, it is sufficiently distinct. Is white, tasteless, insoluble in water, alcohol, and ether; and when heated with hydrate of lime, is entirely converted into carbonic acid and benzole. If heated alone, a portion sublimates, unaltered, and another part passes into carbonic acid and benzole. Nearly all the salts of this acid are crystallizable.

Terebenzic acid. $\text{C}_{14}\text{H}_7\text{O}_4 = \text{C}_{14}\text{H}_6\text{O}_3 + \text{HO}$. Closely resembles benzoic acid, from which it differs only by one eq. of hydrogen. The two need not be confounded, however, for the terebenzic acid is decomposed by boiling water, and crystallizes in needles instead of laminæ. It moreover melts at 336° , while benzoic fuses at 248° .

Terechrysic acid. Syn. *Terechrysic acid*. $\text{C}_6\text{H}_4\text{O}_5 = \text{C}_6\text{H}_3\text{O}_4 + \text{HO}$. An orange-yellow, deliquescent mass, soluble in water, alcohol, and ether. Forms soluble salts, with a large number of bases.

In the resinous mass from which these three acids were separated, Cailliot detected three substances, allied in physical and chemical properties to the natural resins. The first, *a*, $\text{C}_{40}\text{H}_{24}\text{O}_{20}$, insoluble in alcohol and alkalies, corresponding to the sub-resins; the second, *b*, $\text{C}_{40}\text{H}_{20}\text{O}_{10}$, soluble in alcohol, and insoluble in alkalies, and corresponding to the neutral resins; for example, abietin; and, thirdly, *c*, $\text{C}_{40}\text{H}_{24}\text{O}_{16}$, soluble in alcohol, and in alkalies, and very analogous to colophony.

Action of hydrochloric acid upon the oil. The products are a liquid and a solid compound.

1. *Hydrochlorate of térébenthèn* (solid). Syn. Artificial Camphor. Muriate of CAMPHEN or of DADYL. Formula $\text{C}_{20}\text{H}_{16}$, HCl . Crystallizes from boiling alcohol in flexible needles, which are white and insoluble in water, but soluble in ether and in alcohol. Fuses at 302° , boils at 329° , and sublimates, only partially altered. By distillation over lime heated to redness, the HCl acid is removed, and Dadyl (Tereben, Camphilen) passes over. (See CAMPHEN.)

2. *Liquid Muriate of Térébenthèn*. Syn. Hydrochlorate of Térébèn. Formula $\text{C}_{20}\text{H}_{16}$, HCl . A colorless, volatile liquid, insoluble in and lighter than water, soluble in alcohol and ether. By distillation over caustic lime, it yields *Pencyl*, (Pencylen, Térébylèn), for the properties of which see CAMPHEN.

Action of Sulphuric acid upon Oil of Terpentine. The careful addition of $\frac{1}{2}$ of oil of vitriol to cooled essence of terpentine reddens and thickens it; and this mixture, on repose, gives a liquid which by distillation yields térébèn and colophèn. (See CAMPHEN, p. 405.)

TERRA DE JAPONICA. See CATECHU.

TERRA DE SIENNA. *Tech. Chem.* A mineral product, used as a pigment. In the raw state it is brownish, and occasionally lighter. Spec. grav. of the brown is 2.1. When burned, it becomes reddish brown. Mauss's Analysis of Sienna dried at 212° , gave:—

	Brown lumps.	Yellow lumps.
Sesquioxide of iron.....	66.0	28.8
Oxide of manganese....	3.4	1.1
Arsenic acid.....	8.7	0.5
Silica.....	8.0	63.0
Water	13.3	4.6

The content of arsenic, therefore, renders it a very injurious color.

TESSELITE. See APOPHYLLITE.

TEST. *Chem.* Syn. Reagent. A chemical agent, by which the presence of a body is detected. Thus, for example, baryta forms insoluble white precipitate, with sulphuric acid. Silver gives a white precipitate, with HCl acid, soluble in ammonia, and this characteristic behavior renders these two acids appropriate reagents for detecting the presence of the other two substances, and vice versa. So, likewise, protoxide of iron always gives a dark blue precipitate, insoluble in acids, with red prussiate of potassa. The peroxide of that metal gives none, and these reactions being peculiar to these bodies serve for their recognition. The "test series" necessarily comprises a number of reagents, but does not require one for every substance, since certain reagents produce well-marked differences of behaviour to a number of different bodies. These are termed general tests. Others again produce peculiar and characteristic reactions with one substance, and are termed special tests. For their mode of preparation and application, and for their behaviour, see the works on Qualitative Analysis, by Rose, Fresenius, Nood, and others.

TETARTIN. See ALBITE.

TETRADYMITE. See TELLURIC BISMUTH.

TETRAKLASITE. See SCAPOLITE.

TETRAPHYLIN. See TRIPHYLIN.

THAKCETONE. *Chem.* One of a series of products formed by the contemporaneous action of sulphur and ammonia upon ACETONE. A brownish yellow mass, resembling varnish, soluble in water and alcohol and slightly in ether. It is neutral to vegetable colors.

Therythrin, a brownish red body, soluble in alcohol, but nearly insoluble in water and pure ether, is another of the series. (*Chem. Gaz.* i. 677.)

THALLITE. See EPIDOTE.

THALLOCLOR. Syn. Chlorothalle. A green, flocculent matter, obtained by Schnedderman and Knop (*Chem. Gaz.* iv. 31) from the *Cetraria Islandica*, (see CETRARIN), which owes the color of its spherical cells to this substance.

THEBAIN. See OPIUM.

THEIN. See TEA.

THENARDITE. *Min.* Cryst. Right rhombic, with the same cleavage. $\text{H} = 2-2.5$.

G. = 2.73. White, vitreous, translucent, becomes covered with a white powder by exposure to light. It colors the flame yellow, fuses, sinks into the coal, and is reduced to sulphuret; soluble in water. Form. NaO, SO_3 . From Espartine, near Aranjuez, Spain.

THEOBROMIN. Formula $\text{C}_9\text{H}_5\text{N}_3\text{O}_2$ (Woskresensky), or $\text{C}_7\text{H}_4\text{N}_2\text{O}_2$ (Glisson). Is extracted from the seeds of the CACAO THEOBROMA, by the same process as caffeine from coffee. Like caffeine it is, according to Liebig, closely related to urea and uric acid,—the similarity exists also in other respects. It forms a white, crystalline powder, unalterable by exposure to air or 212° , but browns at 482° and volatilizes into a crystalline sublimate, leaving a carbonaceous residue. Is sparingly soluble in hot water, less so in alcohol and ether, but dissolves, apparently without decomposition, in boiling baryta water.

Muriate. $\text{C}_7\text{H}_4\text{N}_2\text{O}_2, \text{HCl}$.

Nitrate. Crystallizes in rhombic prisms. Like the muriate, it is readily decomposed by water.

Theobromine and Nitrate of Silver. $\text{AgO}, \text{NO}_5 + \text{C}_7\text{H}_4\text{N}_2\text{O}_2$. Crystallizes in brilliant, silvery needles, which are remarkable for their insolubility.

Theobromine and Chloride of Platinum. $\text{PtCl}_2, 4\text{HO} + \text{C}_7\text{H}_4\text{N}_2\text{O}_2, \text{HCl}$. Crystallizes in beautiful, monoklinometric prisms, which effloresce by long exposure.

When heated with peroxide of lead and sulphuric acid, a product is obtained which imparts a blue color to the skin, and bears some analogy to alloxan. (*Chem. Gaz.* 1847.)

THERMOMETER. An instrument for determining the temperature of a body. Its action being based upon relative expansibility, under the influence of heat and cold, the comparative temperature only, and not the amount of heat is indicated by this means. See EXPANSION and HEAT. It consists of a cylindrical glass stem, with a capillary bore of precise uniformity, and bulb at one extremity. This bulb is to be filled with some fluid of equable expansion; and as mercury has this property in an eminent degree, and moreover, as there is a wide difference between its boiling and freezing points, it is most used for all temperatures below 600° . Alcohol, which does not congeal until -90° by its greater power of dilatation, is more applicable for indicating temperatures below 0° . The air thermometer is sometimes used, and is exceedingly accurate, from the equal expansibility of the air, but as it is very sensitive to slight differences of temperatures, the consequent length of tube required renders it inconvenient for common use, and limits it only to delicate scientific research.

In constructing a mercurial thermometer, the air is expelled, and the bulb filled with metal, which is heated until it appears at the top of the tube, when the end is then closed hermetically, over a spirit lamp. The freezing point is then determined by immersing the bulb in melting ice, and marked with a file upon the stem. In like manner the boiling point is determined by immersion of the bulb in boiling water, and likewise indented upon the stem. The interval between these two points of gra-

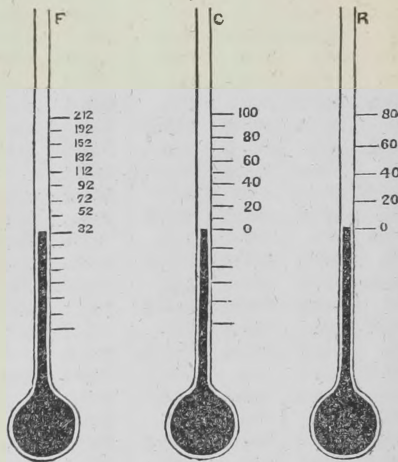
duction, the freezing and boiling points of water, are then apportioned off into degrees. This apportionment varies with the scale employed—the three principal being Fahrenheit's, Celsius (Centigrade), and Reaumur's.

Fig. 90. Fig. 90 represents a thermometer, constructed by Greiner, for chemical purposes. The bulb and stem are closed in a glass tube, containing the scale graduated upon paper. It is very convenient for introducing into tubulures, and is more readily cleansed than those which are fastened by clamps to wooden scales. To be accurate, the base of the thermometer must be uniform, the stem slender, straight, and entirely void of air.

Below is a diagram, (Fig. 91) showing the relative positions of the degrees of the three scales.

Fahrenheit's scale ranges from 32° to 212° ; that of Celsius (Centigrade) from 0° to 100° ; Reaumur's from 0° to 80° . The first is most popular in England and in this country; the second in France; and the third in Russia, Spain, and part of Germany. The scale of Fahrenheit has its zero at 32° below the freezing point of water, and the other two exactly at that point. Therefore, in comparing the degrees of the former with those of the latter, the negative, or those below zero, have a prefix of the minus (—) sign, and the positive, or those above, the plus (+) sign. The diagram (Fig. 91) will present the relative position of the corresponding degrees of the three scales.

Fig. 91.



The following rules will be found convenient for translating the degrees of one scale into those of another:

1. To reduce Centigrade degrees to those of Fahrenheit, multiply by 9, and divide by 5, and to the quotient add 32, that is,—

$$\frac{\text{Cent.} \times 9}{5} + 32 = \text{Fahr.}$$

2. To reduce Fahrenheit's degrees to Centigrade:—

$$\frac{\text{Fahr.} - 32 \times 5}{9} = \text{Cent.}$$

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3. To reduce Reaumur's to Fahrenheit's:—

$$\frac{\text{Reau.} \times 9}{4} + 32 = \text{Fahr.}$$

4. To convert Fahrenheit's to Reaumur's:—

$$\frac{\text{Fahr.} - 32 \times 4}{9} = \text{Reaumur.}$$

Differential Thermometer. This instrument, contrived by Leslie, for determining very slight differences of temperature is a U tube, with a bulb blown at either end. The contained fluid is air and sulphuric acid reddened with carmine. So long as the surrounding temperature is uniform, the pressure of the air in the bulbs upon the liquid column will also be uniform; but so soon as they cease to be affected alike, the greater elasticity of the air on one side will drive the liquid into that bulb whose

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temperature is lowest, and thus, by a nicely adjusted scale, the slightest difference in the temperature of the two bulbs can be detected. When the expansive influence is withdrawn from that bulb which experienced it, the equilibrium of temperature is restored, and the position of the coloured liquid will be accurately balanced.

Kryometer. Pleischl has contrived a thermometer for very low temperatures, which he calls by this title. The thermometric substance is sulphuret of carbon, tinted violet, with iodine. The instrument is 31 centimetres long, and the scale ranges from $+40^{\circ}$ to -120° , Reaumur. (*Pogendorff's Annalen*, lxiii.)

Annexed is a convenient table for showing at a glance the corresponding degrees of Fahrenheit's, Reaumur's, and Centigrade scales.

Fahren- heit.	Reau- mur.	Centi- grade.	Fahren- heit.	Reau- mur.	Centi- grade.	Fahren- heit.	Reau- mur.	Centi- grade.	Fahren- heit.	Reau- mur.	Centi- grade.
600	252.4	315.5	572	240	300	544	227.5	284.4	516.2	215.2	269
599	252	315	571	239.5	299.4	543.2	227.2	284	516	215.1	268.8
598	251.5	314.4	570.2	239.2	299	543	227.1	283.8	515.7	215	268.7
597.2	251.2	314	570	239.1	298.8	542.7	227	283.7	515	214.6	268.3
597	251.1	313.8	569.7	239	298.7	542	226.6	283.3	514.4	214.4	268
596.7	251	313.7	569	238.6	298.3	541.4	226.4	283	514	214.2	267.7
596	250.3	313.3	568.4	238.4	298	541	226.2	282.7	513.5	214	267.5
595.4	250.4	313	568	238.2	297.7	540.5	226	282.5	513	213.7	267.2
595	250.2	312.7	567.5	238	297.5	540	225.7	282.2	512.6	213.6	267
594.5	250	312.5	567	237.7	297.2	539.6	225.6	282	512	213.3	266.6
594	249.7	312.2	566.6	237.6	297	539	225.3	281.6	511.2	213	266.2
593.6	249.6	312	566	237.3	296.6	538.2	225	281.2	511	212.9	266.1
593	249.3	311.6	565.2	237	296.2	538	224.9	281.1	510.8	212.8	266
592.2	249	311.2	565	236.9	296.1	537.8	224.8	281	510	212.4	265.5
592	248.9	311.1	564.8	236.8	296	537	224.4	280.5	509	212	265
591.8	248.8	311	564	236.4	295.5	536	224	280	508	211.5	264.4
591	248.4	310.5	563	236	295	535	223.5	279.4	507.2	211.2	264
590	248	310	562	235.5	294.4	534.2	223.2	279	507	211.1	263.8
589	247.5	309.4	561.2	235.2	294	534	223.1	278.8	506.7	211	263.7
588.2	247.2	309	561	235.1	293.8	533.7	223	278.7	506	210.6	263.3
588	247.1	308.8	560.7	235	293.7	533	222.6	278.3	505.4	210.4	263
587.7	247	308.7	560	234.6	293.3	532.4	222.4	278	505	210.2	262.7
587	246.6	308.3	559.4	234.4	293	532	222.2	277.7	504.5	210	262.5
586.4	246.4	308	559	234.2	292.7	531.5	222	277.5	504	209.7	262.2
586	246.2	307.7	558.5	234	292.5	531	221.7	277.2	503.6	209.6	262
585.5	246	307.5	558	233.7	292.2	530.6	221.6	277	503	209.3	261.6
585	245.7	307.2	557.6	233.6	292	530	221.3	276.6	502.2	209	261.2
584.6	245.6	307	557	233.3	291.6	529.2	221	276.2	502	208.9	261.1
584	245.3	306.6	556.2	233	291.2	529	220.9	276.1	501.8	208.8	261
583.2	245	306.2	556	232.9	291.1	528.8	220.8	276	501	208.4	260.5
583	244.9	306.1	555.8	232.8	291	528	220.4	275.5	500	208	260
582.8	244.8	306	555	232.4	290.5	527	220	275	499	207.5	259.4
582	244.4	305.5	554	232	290	526	219.5	274.4	498.2	207.2	259
581	244	305	553	231.5	289.4	525.2	219.2	274	498	207.1	258.8
580	243.5	304.4	552.2	231.2	289	525	219.1	273.8	497.7	207	258.7
579.2	243.2	304	552	231.1	288.8	524.7	219	273.7	497	206.6	258.3
579	243.1	303.8	551.7	231	288.7	524	218.6	273.3	496.4	206.4	258
578.7	243	303.7	551	230.6	288.3	523.4	218.4	273	496	206.2	257.7
578	242.6	303.3	550.4	230.4	288	523	218.2	272.7	495.5	206	257.5
577.4	242.4	303	550	230.2	287.7	522.5	218	272.5	495	205.7	257.2
577	242.2	302.7	549.5	230	287.5	522	217.7	272.2	494.6	205.6	257
576.5	242	302.5	549	229.7	287.2	521.6	217.6	272	494	205.3	256.6
576	241.7	302.2	548.6	229.6	287	521	217.3	271.6	493.2	205	256.2
575.6	241.6	302	548	229.3	286.6	520.2	217	271.2	493	204.9	256.1
575	241.3	301.6	547.2	229	286.2	520	216.9	271.1	492.8	204.8	256
574.2	241	301.2	547	228.9	286.1	519.8	216.8	271	492	204.4	255.5
574	240.9	301.1	546.8	228.8	286	519	216.4	270.5	491	204	255
573.8	240.8	301	546	228.4	285.5	518	216	270	490	203.5	254.4
573	240.4	300.5	545	228	285	517	215.5	269.4	489.2	203.2	254

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Fahren- heit.	Reau- mur.	Centi- grade.	Fahren- heit.	Reau- mur.	Centi- grade.	Fahren- heit.	Reau- mur.	Centi- grade.	Fahren- heit.	Reau- mur.	Centi- grade.
489	203.1	253.8	451.4	186.4	233	414	169.7	212.2	376.2	153	191.2
488.7	203	253.7	451	186.2	232.7	413.6	169.6	212	376	152.9	191.1
488	202.6	253.3	450.5	186	232.5	413	169.3	211.6	375.8	152.8	191
487.4	202.4	253	450	185.7	232.2	412.2	169	211.2	375	152.4	190.5
487	202.2	252.7	449.6	185.6	232	412	168.9	211.1	374	152	190
486.5	202	252.5	449	185.3	231.6	411.8	168.8	211	373	151.5	189.4
486	201.7	252.2	448.2	185	231.2	411	168.4	210.5	372.2	151.2	189
485.6	201.6	252	448	184.9	231.1	410	168	210	372	151.1	188.8
485	201.3	251.6	447.8	184.8	231	409	167.5	209.4	371.7	151	188.7
484.2	201	251.2	447	184.4	230.5	408.2	167.2	209	371	150.6	188.3
484	200.9	251.1	446	184	230	408	167.1	208.8	370.4	150.4	188
483.8	200.8	251	445	183.5	229.4	407.7	167	208.7	370	150.2	187.7
483	200.4	250.5	444.2	183.2	229	407	166.6	208.3	369.5	150	187.5
482	200	250	444	183.1	228.8	406.4	166.4	208	369	149.7	187.2
481	199.5	249.4	443.7	183	228.7	406	166.2	207.7	368.6	149.6	187
480.2	199.2	249	443	182.6	228.3	405.5	166	207.5	368	149.3	186.6
480	199.1	248.8	442.4	182.4	228	405	165.7	207.2	367.2	149	186.2
479.7	199	248.7	442	182.2	227.7	404.6	165.6	207	367	148.9	186.1
479	198.6	248.3	441.5	182	227.5	404	165.3	206.6	366.8	148.8	186
478.4	198.4	248	441	181.7	227.2	403.2	165	206.2	366	148.4	185.5
478	198.2	247.7	440.6	181.6	227	403	164.9	206.1	365	148	185
477.5	198	247.5	440	181.3	226.6	402.8	164.8	206	364	147.5	184.4
477	197.7	247.2	439.2	181	226.2	402	164.4	205.5	363.2	147.2	184
476.6	197.6	247	439	180.9	226.1	401	164	205	363	147.1	183.8
476	197.3	246.6	438.8	180.8	226	400	163.5	204.4	362.7	147	183.7
475.2	197	246.2	438	180.4	225.5	399.2	163.2	204	362	146.6	183.3
475	196.9	246.1	437	180	225	399	163.1	203.8	361.4	146.4	183
474.8	196.8	246	436	179.5	224.4	398.7	163	203.7	361	146.2	182.7
474	196.4	245.5	435.2	179.2	224	398	162.6	203.3	360.5	146	182.5
473	196	245	435	179.1	223.8	397.4	162.4	203	360	145.7	182.2
472	195.5	244.4	434.7	179	223.7	397	162.2	202.7	359.6	145.6	182
471.2	195.2	244	434	178.6	223.3	396.5	162	202.5	359	145.3	181.6
471	195.1	243.8	433.4	178.4	223	396	161.7	202.2	358.2	145	181.2
470.7	195	243.7	433	178.2	222.7	395.6	161.6	202	358	144.9	181.1
470	194.6	243.3	432.5	178	222.5	395	161.3	201.6	357.8	144.8	181
469.4	194.4	243	432	177.7	222.2	394.2	161	201.2	357	144.4	180.5
469	194.2	242.7	431.6	177.6	222	394	160.9	201.1	356	144	180
468.5	194	242.5	431	177.3	221.6	393.8	160.8	201	355	143.5	179.4
468	193.7	242.2	430.2	177	221.2	393	160.4	200.5	354.2	143.2	179
467.6	193.6	242	430	176.9	221.1	392	160	200	354	143.1	178.8
467	193.3	241.6	429.8	176.8	221	391	159.5	199.4	353.7	143	178.7
466.2	193	241.2	429	176.4	220.5	390.2	159.2	199	353	142.6	178.3
466	192.9	241.1	428	176	220	390	159.1	198.8	352.4	142.4	178
465.8	192.8	241	427	175.5	219.4	389.7	159	198.7	352	142.2	177.7
465	192.4	240.5	426.2	175.2	219	389	158.6	198.3	351.5	142	177.5
464	192	240	426	175.1	218.8	388.4	158.4	198	351	141.8	177.2
463	191.5	239.4	425.7	175	218.7	388	158.2	197.7	350.6	141.6	177
462.2	191.2	239	425	174.6	218.3	387.5	158	197.5	350	141.3	176.6
462	191.1	238.8	424.4	174.4	218	387	157.7	197.2	349.2	141	176.2
461.7	191	238.7	424	174.2	217.7	386.6	157.6	197	349	140.9	176.1
461	190.6	238.3	423.5	174	217.5	386	157.3	196.6	348.8	140.8	176
460.4	190.4	238	423	173.7	217.2	385.2	157	196.2	348	140.4	175.5
460	190.2	237.7	422.6	173.6	217	385	156.9	196.1	347	140	175
459.5	190	237.5	422	173.3	216.6	384.8	156.8	196	346	139.5	174.4
459	189.7	237.2	421.2	173	216.2	384	156.4	195.5	345.2	139.2	174
458.6	189.6	237	421	172.9	216.1	383	156	195	345	139.1	173.8
458	189.3	236.6	420.8	172.8	216	382	155.5	194.4	344.7	139	173.7
457.2	189	236.2	420	172.4	215.5	381.2	155.2	194	344	138.6	173.3
457	188.9	236.1	419	172	215	381	155.1	193.8	343.4	138.4	173
456.8	188.8	236	418	171.5	214.4	380.7	155	193.7	343	138.2	172.7
456	188.4	235.5	417.2	171.2	214	380	154.6	193.3	342.5	138	172.5
455	188	235	417	171.1	213.8	379.4	154.4	193	342	137.7	172.2
454	187.5	234.4	416.7	171	213.7	379	154.2	192.7	341.6	137.6	172
453.2	187.2	234	416	170.6	213.3	378.5	154	192.5	341	137.3	171.6
453	187.1	233.8	415.4	170.4	213	378	153.7	192.2	340.2	137	171.2
452.7	187	233.7	415	170.2	212.7	377.6	153.6	192	340	136.9	171.1
452	186.6	233.3	414.5	170	212.5	377	153.3	191.6	339.8	136.8	171

THERMOMETER.

THERMOMETER.

Fahren- heit.	Reau- mur.	Centi- grade.	Fahren- heit.	Reau- mur.	Centi- grade.	Fahren- heit.	Reau- mur.	Centi- grade.	Fahren- heit.	Reau- mur.	Centi- grade.
339	136.4	170.5	300.2	119.2	149	263	102.6	128.3	225.5	86	107.5
338	136	170	300	119.1	148.9	262.4	102.4	128	225	85.7	107.2
337	135.5	169.4	299.7	119	148.7	262	102.2	127.7	224.6	85.6	107
336.2	135.2	169	299	118.6	148.3	261.5	102	127.5	224	85.3	106.6
336	135.1	168.8	298.4	118.4	148	261	101.7	127.2	223.2	85	106.2
335.7	135	168.7	298	118.2	147.7	260.6	101.6	127	223	84.9	106.1
335	134.6	168.3	297.5	118	147.5	260	101.3	126.6	222.8	84.8	106
334.4	134.4	168	297	117.7	147.2	259.2	101	126.2	222	84.4	105.5
334	134.2	167.7	296.6	117.6	147	259	100.8	126.1	221	84	105
333.5	134	167.5	296	117.3	146.6	258.8	100.8	126	220	83.5	104.4
333	133.7	167.2	295.2	117	146.2	258	100.4	125.5	219.2	83.2	104
332.6	133.6	167	295	116.9	146.1	257	100	125	219	83.1	103.9
332	133.3	166.6	294.8	116.8	146	256	99.5	124.4	218.7	83	103.7
331.2	133	166.2	294	116.4	145.5	255.2	99.2	124	218	82.6	103.3
331	132.9	166.1	293	116	145	255	99.1	123.8	217.4	82.4	103
330.8	132.8	166	292	115.5	144.4	254.7	99	123.7	217	82.2	102.7
330	132.4	165.5	291.2	115.2	144	254	98.6	123.3	216.5	82	102.5
329	132	165	291	115.1	143.8	253.4	98.4	123	216	81.7	102.2
328	131.5	164.4	290.7	115	143.7	253	98.2	122.7	215.6	81.6	102
327.2	131.2	164	290	114.6	143.3	252.5	98	122.5	215	81.3	101.6
327	131.1	163.9	289.4	114.4	143	252	97.9	122.2	214.2	81	101.2
326.7	131	163.7	289	114.2	142.7	251.6	97.6	122	214	80.9	101.1
326	130.6	163.3	288.5	114	142.5	251	97.3	121.6	213.8	80.8	101
325.4	130.4	163	288	113.7	142.2	250.2	97	121.2	213	80.4	100.5
325	130.2	162.7	287.6	113.6	142	250	96.9	121.1	212	80	100
324.5	130	162.5	287	113.3	141.6	249.8	96.8	121	211	79.5	99.4
324	129.7	162.2	286.2	113	141.2	249	96.4	120.5	210.2	79.2	99
323.6	129.6	162	286	112.8	141.1	248	96	120	210	79.1	98.9
323	129.3	161.6	285.8	112.8	141	247	95.5	119.4	209.7	79	98.7
322.2	129	161.2	285	112.4	140.5	246.2	95.2	119	209	78.6	98.3
322	128.8	161.1	284	112	140	246	95.1	118.9	208.4	78.4	98.0
321.8	128.8	161	283	111.5	139.4	245.7	95	118.7	208	78.2	97.8
321	128.4	160.5	282.2	111.2	139	245	94.6	118.3	207.5	78	97.5
320	128	160	282	111.1	138.9	244.4	94.4	118	207	77.7	97.2
319	127.5	159.4	281.7	111	138.7	244	94.2	117.8	206.6	77.6	97
318.2	127.2	159	281	110.6	138.3	243.5	94	117.5	206	77.3	96.6
318	127.1	158.8	280.4	110.4	138	243	93.8	117.2	205.2	77	96.2
317.7	127	158.7	280	110.2	137.7	242.6	93.6	117	205	76.9	96.1
317	126.6	158.3	279.5	110	137.5	242	93.3	116.6	204.8	76.8	96
316.4	126.4	158	279	109.7	137.2	241.2	93	116.2	204	76.4	95.5
316	126.2	157.7	278.6	109.6	137	241	92.9	116.1	203	76	95
315.5	126	157.5	278	109.3	136.6	240.8	92.8	116	202	75.5	94.4
315	125.7	157.2	277.2	109	136.2	240	92.4	115.5	201.2	75.2	94
314.6	125.6	157	277	108.8	136.1	239	92	115	201	75.1	93.9
314	125.3	156.6	276.8	108.8	136	238	91.5	114.4	200.7	75	93.7
313.2	125	156.2	276	108.4	135.5	237.2	91.2	114	200	74.6	93.3
313	124.8	156.1	275	108	135	237	91.1	113.9	199.4	74.4	93
312.8	124.8	156	274	107.5	134.4	236.7	91	113.7	199	74.2	92.7
312	124.5	155.5	273.2	107.2	134	236	90.3	113.3	198.5	74	92.5
311	124	155	273	107.1	133.8	235.4	90.4	113	198	73.7	92.2
310	123.5	154.4	272.7	107	133.7	235	90.2	112.7	197.6	73.6	92
309.2	123.2	154	272	106.6	133.3	234.5	90	112.5	197	73.3	91.6
309	123.1	153.8	271.4	106.4	133	234	89.7	112.2	196.2	73	91.2
308.7	123	153.7	271	106.2	132.7	233.6	89.6	112	196	72.8	91.1
308	122.6	153.3	270.5	106	132.5	233	89.3	111.6	195.8	72.8	91
307.4	122.4	153	270	105.7	132.2	232.2	89	111.2	195	72.4	90.5
307	122.2	152.7	269.6	105.6	132	232	88.9	111.1	194	72	90
306.5	122	152.5	269	105.3	131.6	231.8	88.8	111	193	71.5	89.4
306	121.7	152.2	268.2	105	131.2	231	88.4	110.5	192.2	71.2	89
305.6	121.6	152	268	104.8	131.1	230	88	110	192	71.1	88.8
305	121.3	151.6	267.8	104.8	131	229	87.5	109.4	191.7	71	88.7
304.2	121	151.2	267	104.4	130.5	228.2	87.2	109	191	70.6	88.3
304	120.9	151.1	266	104	130	228	87.1	108.9	190.4	70.4	88
303.8	120.8	151	265	103.5	129.4	227.7	87	108.7	190	70.2	87.8
303	120.4	150.5	264.2	103.2	129	227	86.6	108.3	189.5	70	87.5
302	120	150	264	103.1	128.9	226.4	86.4	108	189	69.7	87.2
301	119.5	149.4	263.7	103	128.7	226	86.2	107.8	188.6	69.6	87

THERMOMETER.

THERMOMETER.

Fahren- heit.	Reau- mur.	Centi- grade.	Fahren- heit.	Reau- mur.	Centi- grade.	Fahren- heit.	Reau- mur.	Centi- grade.	Fahren- heit.	Reau- mur.	Centi- grade.
188	69.3	86.6	150.8	52.8	66	112	35.5	44.4	74.7	19	23.7
187.2	69	86.2	150	52.4	65.5	111.2	35.2	44	74	18.6	23.3
187	68.9	86.1	149	52	65	111	35.1	43.9	73.4	18.4	23
186.8	68.8	86	148	51.5	64.4	110.7	35	43.7	73	18.2	22.7
186	68.4	85.5	147.2	51.2	64	110	34.6	43.3	72.5	18	22.5
185	68	85	147	51.1	63.9	109.4	34.4	43	72	17.7	22.2
184	67.5	84.4	146.7	51	63.7	109	34.2	42.7	71.6	17.6	22
183.2	67.2	84	146	50.6	63.3	108.5	34	42.5	71	17.3	21.6
183	67.1	83.9	145.4	50.4	63	108	33.8	42.2	70.2	17	21.2
182.7	67	83.7	145	50.2	62.7	107.6	33.6	42	70	16.9	21.1
182	66.6	83.3	144.5	50	62.5	107	33.3	41.6	69.8	16.8	21
181.4	66.4	83	144	49.7	62.2	106.2	33	41.2	69	16.4	20.5
181	66.2	82.7	143.6	49.6	62	106	32.9	41.1	68	16	20
180.5	66	82.5	143	49.3	61.6	105.8	32.8	41	67	15.5	19.4
180	65.7	82.2	142.2	49	61.2	105	32.4	40.5	66.2	15.2	19
179.6	65.6	82	142	48.9	61.1	104	32	40	66	15.1	18.8
179	65.3	81.6	141.8	48.8	61	103	31.5	39.4	65.7	15	18.7
178.2	65	81.2	141	48.4	60.5	102.2	31.2	39	65	14.6	18.3
178	64.9	81.1	140	48	60	102	31.1	38.9	64.4	14.4	18
177.8	64.8	81	139	47.5	59.4	101.7	31	38.7	64	14.2	17.7
177	64.4	80.5	138.2	47.2	59	101	30.6	38.3	63.5	14	17.5
176	64	80	138	47.1	58.8	100.4	30.4	38	63	13.7	17.2
175	63.5	79.4	137.7	47	58.7	100	30.2	37.7	62.6	13.6	17
174.2	63.2	79	137	46.6	58.3	99.5	30	37.5	62	13.3	16.6
174	63.1	78.8	136.4	46.4	58	99	29.7	37.2	61.2	13	16.2
173.7	63	78.7	136	46.2	57.7	98.6	29.6	37	61	12.9	16.1
173	62.6	78.3	135.5	46	57.5	98	29.3	36.6	60.8	12.8	16
172.4	62.4	78	135	45.8	57.2	97.2	29	36.2	60	12.4	15.5
172	62.2	77.7	134.6	45.6	57	97	28.9	36.1	59	12	15
171.5	62	77.5	134	45.3	56.6	96.8	28.8	36	58	11.5	14.4
171	61.7	77.2	133.2	45	56.2	96	28.4	35.5	57.2	11.2	14
170.6	61.6	77	133	44.9	56.1	95	28	35	57	11.1	13.8
170	61.3	76.6	132.8	44.8	56	94	27.5	34.4	56.7	11	13.7
169.2	61	76.2	132	44.5	55.5	93.2	27.2	34	56	10.6	13.3
169	60.8	76.1	131	44	55	93	27.1	33.9	55.4	10.4	13
168.8	60.8	76	130	43.5	54.4	92.7	27	33.7	55	10.2	12.7
168	60.4	75.5	129.2	43.2	54	92	26.6	33.3	54.5	10	12.5
167	60	75	129	43.1	53.9	91.4	26.4	33	54	9.7	12.2
166	59.5	74.4	128.7	43	53.7	91	26.2	32.7	53.6	9.6	12
165.2	59.2	74	128	42.6	53.3	90.5	26	32.5	53	9.3	11.6
165	59.1	73.9	127.4	42.4	53	90	25.7	32.2	52.2	9	11.2
164.7	59	73.7	127	42.2	52.7	89.6	25.6	32	52	8.9	11.1
164	58.6	73.3	126.5	42	52.5	89	25.3	31.6	51.8	8.8	11
163.4	58.4	73	126	41.8	52.2	88.2	25	31.2	51	8.4	10.5
163	58.2	72.7	125.6	41.6	52	88	24.9	31.1	50	8	10
162.5	58	72.5	125	41.3	51.6	87.8	24.8	31	49	7.5	9.4
162	57.7	72.2	124.2	41	51.2	87	24.4	30.5	48.2	7.2	9
161.6	57.6	72	124	40.9	51.1	86	24	30	48	7.1	8.9
161	57.3	71.6	123.8	40.8	51	85	23.5	29.4	47.7	7	8.7
160.2	57	71.2	123	40.4	50.5	84.2	23.2	29	47	6.6	8.3
160	56.8	71.1	122	40	50	84	23.1	28.9	46.4	6.4	8
159.8	56.8	71	121	39.5	49.4	83.7	23	28.7	46	6.2	7.7
159	56.4	70.5	120.2	39.2	49	83	22.6	28.3	45.5	6	7.5
158	56	70	120	39.1	48.9	82.4	22.4	28	45	5.7	7.2
157	55.5	69.4	119.7	39	48.7	82	22.2	27.7	44.6	5.6	7
156.2	55.2	69	119	38.6	48.3	81.5	22	27.5	44	5.3	6.6
156	55.1	68.9	118.4	38.4	48	81	21.7	27.2	43.2	5	6.2
155.7	55	68.7	118	38.2	47.7	80.6	21.6	27	43	4.9	6.1
155	54.6	68.3	117.5	38	47.5	80	21.3	26.6	42.8	4.8	6
154.4	54.4	68	117	37.7	47.2	79.2	21	26.2	42	4.4	5.5
154	54.2	67.7	116.6	37.6	47	79	20.9	26.1	41	4	5
153.5	54	67.5	116	37.3	46.6	78.8	20.8	26	40	3.5	4.4
153	53.7	67.2	115.2	37	46.2	78	20.4	25.5	39.2	3.2	4
152.6	53.6	67	115	36.9	46.1	77	20	25	39	3.1	3.9
152	53.3	66.6	114.8	36.8	46	76	19.5	24.4	38.7	3	3.7
151.2	53	66.2	114	36.4	45.5	75.2	19.2	24	38	2.6	3.3
151	52.9	66.1	113	36	45	75	19.1	23.8	37.4	2.4	3

THERYTHRIN.

THORINUM.

Fahren- heit.	Reau- mur.	Centi- grade.	Fahren- heit.	Reau- mur.	Centi- grade.	Fahren- heit.	Reau- mur.	Centi- grade.	Fahren- heit.	Reau- mur.	Centi- grade.
37	2.2	2.7	17.6	— 6.4	— 8	— 2	—15.1	—18.9	21	—23.5	—29.4
36.5	2	2.5	17	— 6.6	— 8.3	— 2.2	—15.2	—19	22	—24	—30
36	1.7	2.2	16.2	— 7	— 8.7	— 3	—15.5	—19.4	23	—24.4	—30.5
35.6	1.6	2	16	— 7.1	— 8.9	— 4	—16	—20	23.8	—24.8	—31
35	1.3	1.6	15.8	— 7.2	— 9	— 5	—16.4	—20.5	24	—24.9	—31.1
34.2	1	1.2	15	— 7.5	— 9.4	— 5.8	—16.8	—21	24.2	—25	—31.2
34	0.9	1.1	14	— 8	—10	— 6	—16.8	—21.1	25	—25.3	—31.6
33.8	0.8	1	13	— 8.4	—10.5	— 6.2	—17	—21.2	25.6	—25.6	—32
33	0.4	0.5	12.2	— 8.8	—11	— 7	—17.3	—21.6	26	—25.7	—32.2
32	0	0	12	— 8.9	—11.1	— 7.6	—17.6	—22	26.5	—26	—32.5
31	—0.4	—0.5	11.7	— 9	—11.2	— 8	—17.7	—22.2	27	—26.2	—32.7
30.2	—0.8	—1	11	— 9.3	—11.6	— 8.5	—18	—22.5	27.4	—26.4	—33
30	—0.9	—1.1	10.4	— 9.6	—12	— 9	—18.2	—22.7	28	—26.6	—33.3
29.7	—1	—1.2	10	— 9.7	—12.2	— 9.4	—18.4	—23	28.7	—27	—33.7
29	—1.3	—1.6	9.5	—10	—12.5	—10	—18.6	—23.3	29	—27.1	—33.8
28.4	—1.6	—2	9	—10.2	—12.7	—10.7	—19	—23.7	29.2	—27.2	—34
28	—1.7	—2.2	8.6	—10.4	—13	—11	—19.1	—23.8	30	—27.5	—34.4
27.5	—2	—2.5	8	—10.6	—13.3	—11.2	—19.2	—24	31	—28	—35
27	—2.2	—2.7	7.2	—11	—13.7	—12	—19.5	—24.4	32	—28.4	—35.5
26.6	—2.4	—3	7	—11.1	—13.9	—13	—20	—25	32.8	—28.8	—36
26	—2.6	—3.3	6.8	—11.2	—14	—14	—20.4	—25.5	33	—28.9	—36.1
25.2	—3	—3.7	6	—11.5	—14.4	—14.8	—20.8	—26	33.2	—29	—36.2
25	—3.1	—3.8	5	—12	—15	—15	—20.9	—26.1	34	—29.3	—36.6
24.8	—3.2	—4	4	—12.4	—15.5	—15.2	—21	—26.2	34.6	—29.6	—37
24	—3.5	—4.4	3.2	—12.8	—16	—16	—21.3	—26.6	35	—29.7	—37.2
23	—4	—5	3	—12.9	—16.1	—16.6	—21.6	—27	35.5	—30	—37.5
22	—4.4	—5.5	2.7	—13	—16.2	—17	—21.7	—27.2	36	—30.2	—37.7
21.2	—4.8	—6	2	—13.3	—16.6	—17.5	—22	—27.5	36.4	—30.4	—38
21	—4.9	—6.1	1.4	—13.6	—17	—18	—22.2	—27.7	37	—30.6	—38.3
20.7	—5	—6.2	1	—13.7	—17.2	—18.4	—22.4	—28	37.7	—31	—38.7
20	—5.3	—6.6	0.5	—14	—17.5	—19	—22.6	—28.3	38	—31.1	—38.9
19.4	—5.6	—7	0	—14.2	—17.7	—19.7	—23	—28.7	38.2	—31.2	—39
19	—5.7	—7.2	—0.4	—14.4	—18	—20	—23.1	—28.9	39	—31.5	—39.4
18.5	—6	—7.5	—1	—14.6	—18.3	—20.2	—23.2	—29	40	—32	—40
18	—6.2	—7.7	—1.7	—15	—18.7						

THERYTHRIN. See THAKCETONE.

THIALDIN. *Chem.* A new artificial, organic base, obtained by Wöhler and Liebig in beautiful large crystals, by passing sulphuretted hydrogen through a slightly ammoniacal aqueous solution of aldehydammonia. Is soluble in alcohol and ether, but insoluble in water, fusible and volatile, and neutralizes the strongest acids, forming crystallizable compounds. Heated with lime, it gives leucolin or quinolein. Formula $C_{12}H_{13}NS_4$; of the muriate, $C_{12}H_{13}NS_4$, HCl; of the nitrate, $C_{12}H_{13}NS_4$, NO_3 , HO.

THIALIC OIL. *Chem.* The ethereal mixture formed by the distillation of sulphuret of potassium with sulphate of ethyl and potassa, in the preparation of bisulphuret of ETHYL.

THIOFURFOLE. *Chem.* Obtained by the action of sulphuretted hydrogen upon an alcoholic solution of furfuramide. A pulverulent substance, of a yellow color, and composition $C_{10}H_8S_2O_2$. (*Cahours, Chem. Gaz.* 6, 459.)

THIONURIC ACID. See URIC ACID.

THIOSINNAMIN. See MUSTARD.

THLAPSI ARVENSE, OIL OF. Obtained by distilling together the seeds and the cold water in which they have been macerated. Is colorless, and consists according to Pleis, of oil of garlic and mustard. (*Chem. Gaz.* iv. 252.)

THOMSONITE. *Min.* Comptonite, Chalkite, (mesotype, in part.) Cryst. Right rhom-

bic, prismatic, with two rectangular cleavages, also amorphous. H. = 4.75. G. = 2.3—2.4. White (brown); vitreous, subpearly; transparent, translucent; brittle, with uneven fracture. Behavior like the zeolites; gelatinizes with acids.

Form. $3 NaO, SiO_3 + 3 (Al_2O_3, SiO_3) + 6 HO$.
 $2 [3 CaO, SiO_3 + 3 (Al_2O_3, SiO_3) + 6 HO]$

The general formula may be given as $3 RO, SiO_3 + 3 (Al_2O_3, SiO_3) + 6 HO$. It occurs in lava of Vesuvius, in basalt, amygdaloid, &c.

THORINUM. *Chem.* Thorium. One of the rarest elements, discovered by Berzelius in 1828, in a mineral called thorite. 1. The metal obtained by heating chloride of thorinum and potassium in a tube, forms a heavy lead-gray powder, which, when heated in the air, burns with great brilliancy to thorina. Sym. Th. Eq. = 59.51 (743.86, O = 100, *Berz.*)

2. *Thorina, ThO. Prep.* Digest powdered thorite in muriatic acid; evaporate to dryness to render silica insoluble; extract the residue with muriatic acid and water, precipitate tin and lead by sulphohydrogen; precipitate thorina and other oxides by ammonia; wash and dissolve in sulphuric acid, evaporate at a gentle heat, and when the insoluble sulphate of thorina has deposited, pour off the mother liquid, wash the residue with boiling water, dry and ignite; pure thorina remains as a

white, infusible powder, insoluble in nitric and muriatic acids, soluble in hot oil of vitriol. Some thorina may still be obtained from the mother liquor. The *hydrate* is obtained from the sulphate by solution in cold water, precipitation with potassa, and washing with water, as a flocculent precipitate, like alumina, readily soluble in acids, while moist. The salts of thorina are colorless, and have a pure astringent taste; caustic alkali throws down white hydrate, insoluble in excess of the precipitant; carbonated alkali, white carbonate, soluble in excess of the precipitant; white precipitates are produced by phosphate of soda, tungstate, molybdate, arseniate, ferropurssiate, and oxalate of alkali. Excess of crystals of sulphate of potassa throw down sulphate of thorina and potassa.

3. *Sulphuret of Th.* formed by thorinum in vapor of sulphur, is a yellow powder, difficult of decomposition except by hot aqua regia. It unites similarly to phosphorus, in vapor, forming a dark gray, metallic phosphuret.

4. *Haloid Salts.* Dry *chloride*, ThCl , is obtained by charring thorina and sugar, and passing a stream of chlorine over it in an ignited porcelain tube, as sublimed white crystals. The hydrated salt is obtained simply by solution of the earth in muriatic acid and evaporating, when it forms a crystalline, very deliquescent mass. It unites with chloride of potassium to a double salt, obtained by direct mixture and evaporation, as a deliquescent, crystalline mass; when this is dried and ignited in a stream of muriatic gas, the dry salt is obtained. The *bromide*, ThBr , is very deliquescent, uncrystallizable, and forms a double salt with bromide of potassium. The *fluoride*, ThF , obtained like the chloride, is a white insoluble powder; its compound with fluoride of potassium is also white and insoluble.

5. *Oxysalts.* *Sulphate*, ThSO_3 , is obtained by digesting for some time thorina with a mixture of two pts. of oil of vitriol, and one pt. of water, and driving off the excess of acid. It is very soluble if thrown at once into much water, and by evaporating above 68° , deposits crystals with two eq. water, by spontaneous evaporation, with 5 HO. The double sulphate, with potassa, is best obtained by adding to the solution of sulphate of thorina a hot saturated solution of sulphate of potassa as long as it precipitates. On cooling, all the thorina is thrown down as the double sulphate, with the form. $\text{KO}, \text{SO}_3 + \text{ThO}, \text{SO}_3 + \text{HO}$. The *nitrate* evaporates to a crystalline mass, which, with its double salt with potassa, is very soluble in water and alcohol. Thorina has so much affinity for carbonic acid, that its hydrate attracts it from the air, and carbonated alkali throws down a hydrocarbonate, insoluble in carbonic acid water. The hydrate and carbonate are quite soluble in strong carbonate of ammonia or potassa.

THORITE. *Min.* Massive and compact. H. above 6. G. = 4.63. Black; vitreous on a fresh surface; resinous on an exposed surface; brittle, with conchoidal fracture and dark brown streak. In a closed tube, it yields water, and becomes brownish red; infusible; soluble in borax and mic. salt, giving iron, and in the latter silica; gives a yellowish brown

slag with soda, and shows manganese on platinum foil; gelatinizes with muriatic acid. Form. $3 \text{ThO}, \text{SiO}_3 + 3 \text{HO}$. From Brevig, Norway. It was in this mineral Berzelius discovered thorina.

THRAULITE. See HISINGERITE.

THROMBOLITE. *Min.* An amorphous phosphate of copper from Retzbanya, Hungary. According to Plattner's analysis, its form. is nearly $2 \text{CuO}, \text{PO}_3 + 4 \text{HO}$.

THUJA OIL. Occurs in the common *lignum vitæ* (*Thuja occidentalis*). When fresh is colorless, but yellows rapidly, and dissolves readily in alcohol and ether. Schweizer (*Journ. für Prakt. Chem.* 30, p. 376) considers it a mixture of at least two distinct oxygeniferous oils. Subjected to distillation, it commences to boil at 374° , and gives between 380° and 387° a colorless product; between 387° and 403° , the liquid passes over yellow, and leaves a slight red-colored residue.

Potassa oxidizes the oil without disengaging hydrogen, and resinifies it, and by saturating the accompanying alkaline liquid with an acid, an oil is obtained having the characteristics of *carracrole*.

Iodine transforms the oil into new products, among which is the carburetted hydrogen; *thujon* boiling between 329 and 347° .

THUMITE. See AXINITE.

THURINGITE. *Min.* Massive, granular. Olive-green; pearly. Form. $3 (3 \text{FeO}, \text{SiO}_3) + 2 \text{Fe}_2\text{O}_3, \text{SiO}_3 + 9 \text{HO}$. From an iron mine near Saalfeld. It may be viewed as a hydrated Lievrite. *Rammelsb.*

THYME, OIL OF. Distilled from the herbaceous portion of the *Thymus vulgaris*. According to Doveri, it consists of two distinct oils, one $\text{C}_{34}\text{H}_{26}\text{O}$, boiling at 346° , and the other, $\text{C}_{40}\text{H}_{30}\text{O}_7$, boiling at 455° , and giving a vapour of 5.511 sp. grav. The latter is, after repeated distillations over anhydrous phosphoric acids, converted, by the loss of water, into $\text{C}_{40}\text{H}_{26}$.

TILE ORE. See RED COPPER-ORE.

TIN. *Chem.* Ger. Zinn. Fr. Etain. Lat. Stannum. *Alchem.* Jupiter. It was known in very ancient times, and there is good reason for believing that tin was obtained by the Phenicians from Cornwall and Spain, at least 1000 B. C. It occurs mostly as oxide, in tin-ore; less frequently, as sulphuret, in tin-pyrites; in small quantities in some epidotes, rutile, &c., in meteoric iron, and in Saidschützer mineral water.

Metallurgic Treatment of Tin-ore.

Prep. The crude ores are concentrated by stamping and washing, the purer stream-tin, &c. being worked separately from the more impure ores. The assay of the ore, crude or prepared by roasting, is made in a rough way, by taking a little out of each lot of ore, powdering them to get an average, mixing 2 ounces of the powder with nearly a drachm (or 4 pr. ct.) of ground coal, heating in an open crucible to reduce, and pouring the melted tin into a mould; the particles remaining in the crucible are obtained by pulverizing and separating them.

Roasting. The prepared ores are first roasted in a reverberatory similar to that for roasting copper ores, except that the fumes should be

conducted into chambers for condensing arsenious acid. Sulphur and arsenic are thus roasted off, and the metals oxidized, while a portion of sulphate of copper is formed. The calcined ore is exposed to the air for some days, to oxidize a portion of remaining sulphuret, put into tubs of water, which extracts the soluble sulphates, again washed to concentrate the ore and separate the better from the inferior qualities, which are separately treated. The solution of sulphates is precipitated by metallic iron, and all the copper thus obtained.

Reduction. The reduction of the ore is effected either in reverberatories or a small blast-furnace. The latter is used at Altenberg, Geyer, Ehrenfriedersdorf, &c., in Germany, and for stream-tin, in England. The ores are concentrated to about 50 pr. ct. tin; and for one operation, 18 cwt. of these are taken, with some previous residues, and 65 pr. ct. tin slag; from which some 6½ cwt. of finer metal are first obtained, and from slags, &c., 3 cwt. more. The slags, scorïæ, &c., are reworked, until almost all the metal is extracted.

The reverberatories, with basin-shaped hearths, are used for the ordinary tin ores in Cornwall. The ore, fine coal, and some slaked lime are well mixed, damped with water, thrown into the furnace in charges of from 12—16 cwt., and the heat gradually raised, to reduce the oxide. When reduced, the charge is stirred, to separate the tin and remove the scorïæ. The scorïæ is divided into three kinds: ¾ of the whole, being very poor, is thrown away; another portion is stamped, washed, and separately smelted, to form an inferior tin; and a third, rich in tin, is resmelted. When the scorïæ has been removed, the channel is opened, through which the tin flows into a receiving basin, where the scorïæ and tin separate, and the latter is ladled out and cast into blocks.

Eliquescent. The blocks are laid on the hearth of a reverberatory similar to that used for reduction, with a concave hearth, a moderate fire is given, by which the purer metal is eliquated from the more infusible alloys, and some scorïæ, and runs into the refining basin, while the alloys remain on the hearth. Other blocks are laid on successively, until some 5 tons of metal are eliquated. The fire is increased to fuse the residuum, which is run off into a separate basin, where, after repose, the less impure metal is removed from a useless alloy, and subjected to repurification.

Refining. Billets of green wood are plunged into the refining basin (*poling*), and by their evolution of gas cause an ebullition which brings a scum of oxides to the surface, and causes the rest of the metal to separate into layers, the purest being at the top, under the scum, a less pure in the middle, and a more impure alloy at the bottom. The froth, containing oxides of tin, iron, &c., is skimmed off and thrown back into the furnace, and the tin below is ladled out and cast into cast-iron moulds. The top layer yields the finest tin, *refined tin*, and the lowest is worked with freshly-reduced tin; the greater part being cast into large blocks, receives the name *block tin*. Refining is also performed by *tossing*, in which a workman ladles out some tin and pours it from a height into the bath. The scum in this case

is carefully removed, and the metal kept in a state of quiet fusion, by which the same takes place into layers of purer and impure metal. To make *grain tin*, a block is heated until it becomes brittle, and being let fall, breaks into semicrystalline, elongated pieces.

The amount of tin annually produced in the world, amounts to about 10,000 tons, of which Cornwall and Devonshire, in England, furnish nearly one half.

Manufacture of Tin-plate or Sheet-tin.

Tin-plate, or rather tinned plate, consists of sheet-iron alloyed and coated externally with pure tin. Sheet-iron of good quality is cut into the sizes required, bent into a $\wedge$ form, heated to redness in a reverberatory, dipped into dilute muriatic acid, drained, and again heated, to *scale* the whole surface. They are then beat level and smooth, passed cold through chilled rollers, immersed in the *lyes*, a weak bath of fermenting bran-water, pickled by agitation for some time in a bath of dilute sulphuric acid, scoured in water with sand and hemp, and kept for use in pure water. The cleaned plates, dried by bran, are kept in a bath of melted tallow, *grease-pot*, for an hour, and then passed through a series of rectangular pots. The first is the *tin-pot*, containing a melted mixture of block and grain-tin, covered by grease, into which the plates are dipped, one by one, and kept there for 1½ hours or more, then put on an iron grating to drain, and dipped into the *wash-pot*, which contains pure and fused grain-tin. In this the superfluous tin is removed from the surface. The plate is lifted out, scoured on both sides with a hempen brush, dipped for a moment into the melted tin, in a compartment of the wash-pot, to remove the marks of the brush and give uniform smoothness to the surface, and then immersed in the adjoining *grease-pot*, where some superfluous tin is removed, and collects on the lower edge. The plate is next put into the *empty-pot*, to drain. When cool enough, the lower edge of the plate is dipped into the *list-pot*, containing ¼ inch depth of melted tin, by which the accumulation of tin on this edge is melted off, leaving a dull edge, to be seen on all sheets of tin. The plate is then cleansed with bran, and packed. What is commonly called *block-tin*, is made from heavier sheet-iron, and coated more carefully and heavier with tin. By the operation of tinning, a portion of this metal penetrates the iron, and alloys with it, the quantity of tin increasing from the interior to the outer surface, which is a coating of pure tin.

The surface of tin plate is rendered crystalline by brushing its surface with nitric acid, slightly diluted, and containing some salamoniac or common salt in solution, and immediately immersing it in water, to stop the action at any desired point. By cooling parts of the surface with cold water, the crystallization is varied, as it is also by directing the point of a blowpipe flame to different parts of the surface. After cleansing the surface with the gentlest friction, it is varnished.

TIN AND ITS METALLOIDAL COMPOUNDS.

1. *Tin.* Commercial tin is purified by keep-

ing it fused in the air, when it separates into strata of different purity, or by stirring the melted metal in the air, to oxidize foreign metals with some tin, or lastly by converting it wholly into oxide by nitric acid, washing the oxide with muriatic acid and water, and reducing it in a crucible with charcoal. It is a brilliant white metal, with a faint lead-tint when compared with silver, crystallizing in the quadratic system (?); spec. grav. = 7.29, of the rolled 7.299; harder than lead, emits a peculiar noise when bent, called the *cry* of tin, which is attributed to the sliding of the crystalline plates over each other; is not very extensible, but is malleable into thin sheets, *tin-foil*; fuses at 440° — 446° ; boils at a white heat, and burns with a blue flame to binoxide; at a lower heat it forms a dross on the surface of mixed oxides, *tin-ash*; oxidizes readily with nitric acid to a white, insoluble powder; dipped in a muriatic solution of gold, it becomes black without evolving gas, while zinc blackens with evolution of gas, and lead is unaltered. Sym. Sn (stannum). Eq. 58.82 (735.294, O = 100, Berz.)

2. *Oxygen. a. Oxide of Tin.* Protoxide, SnO . Evaporate a solution of crystallized chloride of tin, containing a piece of metallic tin, to dryness and fusion, mix 3 pts. of it with 2 pts. crystallized carbonate of soda, heat and stir the fused mixture until it is entirely black, extract chloride of sodium after cooling with boiling water, and dry the oxide at a gentle heat. It is less perfectly made by precipitating hydrated oxide, and either drying it in an atmosphere of hydrogen, or boiling it in water. It is a nearly black powder, which becomes crystalline by boiling with a little potassa, while a portion dissolves as binoxide. The hydrate is made by precipitating chloride by an excess of ammonia or carbonate of potassa.

Salts. Generally colorless or yellowish, with acid reaction and disagreeable metallic taste; the neutral or slightly acid salts decompose with water containing air; their tendency to oxidize is a striking property, on which much of the use of tin-crystals, in color-printing, depends. Zinc and cadmium precipitate metallic tin from its salts, except from the acetate; sulphohydrogen and sulphhydrate of ammonium throw down brown sulphuret (except from a strong acid solution), soluble in excess of the latter; and the limits of the reaction are 1 pt. salt to 120,000 pts. water; iodide of potassium gives yellow iodide, which passes under some circumstances into red; ammonia and carbonated alkalies give white hydrate, insoluble in excess of the precipitant, but soluble in potassa, from which it deposits a portion as metal. A white precipitate is produced by phosphate of soda, oxalic acid, the two prussiates of potash, alkaline succinates and benzoates; yellow by croconate of potassa and tincture of galls. The insoluble are soluble in muriatic acid, unless previously ignited.

b. Bin oxide of Tin. Stannic acid, SnO_2 , containing 78.62 pr. ct. metal. It is obtained by calcination of tin in the air; by precipitating with alkali and ignition; or by the action of nitric acid, and ignition. It is a yellowish powder, becoming transiently dark yellow, or orange by heat; reduced by ignition with car-

bon, in hydrogen or carbonic oxide, more easily by heating with cyanide of potassium. The *hydrate* is made by precipitation from bichloride by alkali, or by the action of nitric acid on the metal. But the hydrate made by these two methods has differing properties, and constitutes two modifications, $^a\text{SnO}_2$, made by alkali, and $^b\text{SnO}_2$, made by nitric acid. $^a\text{SnO}_2$ is slightly soluble in nitric acid, $^b\text{SnO}_2$ is insoluble; a is soluble even in dilute sulphuric acid, and not precipitable by boiling, b is insoluble even in oil of vitriol, but it absorbs the acid, swells, and becomes yellow; a is perfectly soluble in muriatic acid, and is not precipitated by boiling; b is scarcely soluble in muriatic acid, but combines with it to a salt, insoluble in muriatic acid, and when the acid is poured off and the residue washed with a little water, it dissolves, but is again precipitated by boiling and by adding muriatic acid; both a and b are soluble in caustic and carbonated alkali, and when precipitated by an acid, exhibit their separate properties as before solution. When b , still moist, is treated with muriatic acid, and, after pouring off the acid, distilled, a passes over; on the other hand, when a in solution is boiled with nitric acid, the greater part of it becomes b ; the salts formed with acids by a are more soluble in water, those by b less soluble. Both oxides unite with alkalies, and act the part of acids, forming *stannates*, but b is dissolved in much larger quantity by alkalies than a . The hydrate of a appears to be 2HO , SnO_2 , that of b , HO , SnO_2 .

Salts. They are colorless or yellow, with an acid test when soluble; the insoluble are soluble in muriatic acid; from their solutions zinc and cadmium throw down tin in dendritic form; sulphuretted hydrogen, alone or with alkali, throws down yellow sulphuret, soluble in the alkalies and sulphide of ammonium; caustic alkalies precipitate white hydrate, soluble in slight excess of potassa; the precipitated hydrate by carbonated alkali is slightly soluble in excess of the precipitant, but separates by standing; that by bicarbonates is insoluble, and that by carbonates of alkaline earths contains no alkali which the others do; phosphate of soda and succinate of ammonia give white precipitates, the succinate removing all the tin from solution; infusion of galls and yellow prussiate of potash produce a yellow jelly; the precipitate produced by boiling bichloride of tin with alkaline acetate or formiate redissolves on cooling, or by washing with cold water.

c. Sesquioxide of Tin. Sn_2O_3 . Neutralize a solution of protochloride of tin by ammonia, and superneutralize a solution perchloride of iron by ammonia; add the latter to the former, this being in excess. The precipitate dries to yellow, translucent grains, soluble in ammonia. b Oxide of tin abstracts protoxide from a cold solution of protochloride, becoming orange-yellow, and probably SnO , 3SnO_2 .

3. *Sulphur. a. Sulphuret of Tin.* SnS . Obtained by fusion of sulphur and tin, pulverizing, and remelting; is crystalline, dark lead-gray, easily reduced to metal by heating with cyanide of potassium, fusible in all proportions with metallic tin, and soluble in muriatic acid with evolution of sulphohydrogen. It is obtained

in the wet way by precipitating protochloride by sulphuretted hydrogen.

b. Sesquisulphuret. Sn_2S_3 . Obtained by heating 3 pts. *a.* with 1 pt. sulphur in a retort; is grayish yellow, metallic; potassa lye extracts from it bisulphuret, and muriatic acid proto-sulphuret.

c. Bisulphuret of Tin. Mosaic gold, Zinnsulfid. SnS_2 . Obtained by heating protochloride, protoxide, or oxide with sulphur. The various proportions are equal pts. tin filings, sulphur, and salammoniac; 4 pts. tin filings, 3 sulphur, 2 salammoniac; 1 pt. amalgam (composed of 12 tin and 6 mercury) with 7 sulphur and 6 salammoniac; 5 protosulphuret of tin and 8 chloride of mercury. Gold-colored, translucent scales, of a peculiar soapy feeling. The yellow precipitate obtained by sulphohydrogen from salts of binoxide, dries to dark yellow, hard lumps. Decomposed by nitric acid, soluble in potassa and in boiling muriatic acid. It forms double salts with metallic sulphurets, sulphostannates; those of the alkalies being obtained by solution of the sulphuret of tin in caustic or sulphuretted alkalies.

4. Phosphuret of Tin. Is obtained of a silver-white color, and crystalline, by throwing phosphorus on melted tin. By saturating dry bichloride of tin by phosphohydrogen, and adding water; a yellow phosphuret separates, of the form. Sn_2P_3 .

5. Alloys. Tin alloys readily by heat with many metals, which it renders more brittle. It alloys with potassium, sodium, selenium, and tellurium. The alloy with arsenic is harder, and has more ring than tin; 15 pts. tin to 1 pt. arsenic crystallizes in broad laminae. The alloy with molybdenum is an infusible powder; with tungsten light brown, porous, and somewhat malleable.

It alloys readily with the noble metals, rendering them brittle; gold with a large quantity of tin is white and brittle, but it will bear 8 pr. ct. tin without losing malleability. 4 tin to 1 iridium is malleable, but hard. It amalgamates readily with mercury; 1 tin to 3 mercury gives cubic crystals. The coating of a mirror is made by spreading tin-foil smoothly on a stone table, rubbing a little mercury (containing tin) over it to amalgamate the surface, pouring a large quantity of mercury on it, pushing a clean plate of glass on this, beginning along one edge, pressing it with weights, and giving the table-top gradually an inclined position to drain off the excess of mercury. Glass bulbs are sometimes coated internally with an amalgam of 1 tin, 1 lead, 2 bismuth, and 10 mercury, which is drawn in, passed all around, and the excess poured out.

With antimony it forms a white, hard, and somewhat ringing metal. Former English pewter contained some 8 pr. ct. antimony. This is now replaced by Britannia metal, which contains other proportions and other metals. See ALLOY. Alloys with bismuth, see under ALLOY, with copper under BRONZE, with lead, &c. under LEAD.

HALOID SALTS.

1. Chlorine. *a. Protochloride of Tin.* SnCl . The anhydrous salt, made by distilling a mixture of equal parts of tin filings and corrosive

sublimate; is a gray, shining mass. The crystallized salt is obtained by dissolving tin in muriatic acid, and evaporating to crystallize. Vessels of copper may be used, provided they contain an excess of tin to the end of the operation. Another solution is sometimes made by calico printers, by dissolving tin in a mixture of 2 pts. nitric to 1 muriatic acid, contained in a vessel surrounded by cold water. The crystals are SnCl , HO . By solution in water, a milkiness is usually occasioned by the air in the water, or by a portion of oxychloride of tin; muriatic acid clears it. Chloride of tin is an excellent reducing agent; it reduces the acids of arsenic to metal, of molybdenum and tungsten to their blue oxides, the higher oxides of manganese, iron, and copper to lower oxides, the oxides of silver and mercury to metal. It forms double salts with the alkalies and alkaline earths. When potassa is added to the chloride in solution, until the precipitate redissolves, and the solution is evaporated in vacuo, a basic salt crystallizes. A basic oxychloride is obtained by adding a large quantity of water to a solution of chloride, or a smaller quantity of potassa than is necessary to decompose it; form. SnCl , $\text{SnO} + 2\text{HO}$; it is soluble in potassa, but deposits metallic tin after some time.

b. Sesquichloride. Sn_2Cl_3 . Obtained by dissolving sesquioxide in muriatic acid; is used to precipitate purple of Cassius. See under GOLD.

c. Bichloride of Tin. SnCl_2 . The anhydrous compound, fuming liquor of Libavius, is obtained by distilling 4 pts. chloride of mercury with 1 pt. tin (amalgamated with a little mercury, and reduced to powder); or by distilling dry sulphate of tin with common salt. It is a colorless, thin liquid, very fuming in the air, not congealing at -20° , boiling at 148° ; 3 pts. of it mixed with 1 pt. water, congeals to a solid mass of crystals. These may also be obtained by dissolving tin in aqua regia by heat, or by oxidizing the protochloride in solution by nitric acid or chlorine. It forms double salts with alkaline chlorides, by mixing them together, the tin-salt being in excess, and evaporating. The salts of potassium and ammonium are anhydrous, that of sodium hydrated and subject to efflorescence. The ammonium salt, *Pink-salt* of the color printer, made by adding salammoniac to a solution of bichloride and crystallizing, dissolves in 3 pts. water at 64° , and bears ebullition; but if diluted and boiled, it precipitates hydrated oxide.

Anhydrous bichloride absorbs sulphuretted hydrogen, forming $2\text{SnCl}_2 + \text{SnS}_2$. When bisulphuret is saturated with chlorine, the brown liquid congeals to yellow crystals, which have the form. $\text{SnCl}_2 + \text{SCl}_2$. The dry chloride absorbs phosphuretted hydrogen, forming a solid with the form. $3\text{SnCl}_2 + \text{PH}_3$. It also absorbs ammonia, forming a white powder, which may be sublimed unaltered; formula $\text{SnCl}_2 + \text{NH}_3$.

2. Bromide of Tin. SnBr . Is white and soluble. The bibromide, SnBr_2 , formed direct from tin and bromine, is fusible, soluble in water, and sublimes unaltered.

3. Iodide of Tin. SnI . Obtained by heating iodine and tin; is brownish red, soluble and

TINCAL.

crystallizable, fusible, and sublimes at a high heat. It absorbs 2NH_3 , and becomes a white powder. It forms double salts with iodides of the alkalies and alkaline earths, the form, being $\text{Alk I} + 2\text{SnI}$, except for ammonia, which is $\text{NH}_4\text{I} + \text{SnI}$. By mixing dry protochloride with chloride of iodine, an orange bi-chloriodide crystallizes out, with the form. SnI , SnCl_2 . Biniiodide of tin, SnI_2 , obtained by dissolving hydrated oxide in iodhydric acid, forms yellow crystals, decomposable by water.

4. *Fluoride of Tin.* SnF . Is very soluble and crystallizable. The bifluoride, SnF_2 , is uncrystallizable, and coagulates, when heated to ebullition. The silico-fluoride, $3\text{SnF}_2 + 2\text{SiF}_3$, is soluble, crystallizable, and lets fall silica when exposed to the air.

OXYSALTS.

1. *Sulphate of Tin.* SnO , SO_3 . Is obtained as a saline mass, by dissolving tin in oil of vitriol, or the acid slightly diluted; soluble in boiling water with a brown color, and crystallizable. Sulphite of tin, SnO , SO_2 , is obtained as a white powder by adding sulphite of soda to chloride of tin. The hyposulphite is soluble. Tin dissolves in sulphurous acid, but forms at the same time some hyposulphite and sulphuret.

Sulphate of binoxide. SnO_2 , 2SO_2 . Is obtained anhydrous by dissolving tin filings in 3 times their weight of boiling oil of vitriol, and evaporating off the excess of acid at a gentle heat, or by dissolving the hydrate in sulphuric acid.

2. *Nitrate of Tin.* SnO , NO_5 . Is obtained only in solution by dissolving the hydrate in nitric acid, and readily decomposes in the air by heat. When tin is acted on by nitric acid of 1.114, a double salt is obtained of NO_5 , with SnO and NH_3 .

Nitrate of binoxide. SnO_2 , 2NO_5 . Is obtained by dissolving the hydrate in cold nitric acid, to saturation, when, if the acid were strong, it crystallizes; it decomposes readily by heat.

3. *Phosphate of Tin.* 2SnO , PO_5 . Obtained by precipitation, is white and fusible to a glass. Borate is white, insoluble, and fuses to an opaque glass. Phosphite, 2SnO , PO_3 , precipitates as a white powder; its solution in muriatic acid is the most powerful reducing agent in the moist way. Phosphite of binoxide is a white, insoluble powder. Chlorate and iodate are very fugitive.

TINCAL. See BORAX.

TIN-ORE. *Min.* Tin stone, Wood tin, Stream tin, Oxide of tin. Zinnerz, Zinnstein. Cryst. Quadratic, usually 1st and 2d vertical prisms, with the 8-hedron. Often twinned on an edge of the 8-hedron. Also fibrous, granular, compact, as in stream and wood tin. $\text{H.} = 6-7$. $\text{G.} = 6.5-7.1$. Brown and black, in wood-tin often gray, white, ochrey-yellow; adamantine, wood-tin dull; subtransparent, opaque; brittle, sub-brittle, with subconchoidal fracture, and gray or pale brown streak. Unaltered by heat in the pincette; on coal reduced by a good inner flame with some difficulty, readily with soda, only decomposed by fusion with alkali. It is essentially binoxide of tin, SnO_2 , with a little iron and manganese, and the Finbo variety with columbic acid. Found in primary rocks, in Cornwall, Zinnwald, Schlackenwald, Galicia, Sweden, Greenland, Malacca, Banca, New

TITANIUM.

Hampshire, Massachusetts, Virginia, but not yet found in workable quantities in the United States.

TIN PYRITES. *Min.* Bell-metal ore, Sulphuret of tin, Zinnkies. Cryst. Regular, cubic; usually massive, granular. $\text{H.} = 4$. $\text{G.} = 4.3-4.4$. Steel gray; metallic; opaque; brittle, with uneven fracture and black streak. Fuses at a strong heat, and coats the coal white with oxide of tin; gives white fumes and sulphurous odor in an open tube; after roasting shows the presence of iron and copper, and with soda, also of tin; gives a hard button with soda and borax of tough and hard copper; soluble in nitric acid. Form. 2FeS , $\text{SnS}_2 + 2\text{Cu}_2\text{S}$, SnS_2 , or perhaps $2\text{Cu}_2\text{S}$, SnS_2 , in which a portion of the Cu_2S is replaced by FeS , and also by ZnS . Only found in Cornwall.

TITANIC ACID. See ANATASE and RUTILE.

TITANIC IRON. *Min.* Syn. Ilmenite, Iserine, Crichtonite, Menakan, Washingtonite, Hystatite, Eisenrose, Basanmelan, Titaniferous iron. Cryst. Hexagonal, one or more rhombs with large end-planes; usually in plates and grains. $\text{H.} = 5-6$. $\text{G.} = 4.5-5$. Iron-black; sub-metallic, with the same streak; opaque; fracture conchoidal; more or less magnetic. Infusible; shows iron with the fluxes, and manganese on platinum foil; gives with mic. salt in the reducing fire a reddish glass, which tin either colors violet or decolorizes; more or less soluble in aqua regia, leaving titanic acid. A great number of analyses have been made of this mineral, which doubtless includes many varieties, and possibly several species. Very different formulæ have been given, from the different content of protoxide and peroxide of iron, the usual one being FeO , $\text{TiO}_2 + x\text{Fe}_2\text{O}_3$; but Rose and Scheerer have declared for a novel view, that the mineral contains sesquioxide of titanium and not titanic acid, and that the oxide of iron found depends upon the deoxidation of peroxide of iron, during solution, its oxygen converting the titanic oxide into acid, so that the formula would be $\left. \begin{matrix} \text{Fe}_2\text{O}_3 \\ \text{Ti}_2\text{O}_3 \end{matrix} \right\}$

Berzelius thinks that this formula is contrary to atomic views, and opposed to the magnetic character of some of the varieties. But the latter objection ceases, if we suppose, as is likely, that some specimens contain magnetic iron, and moreover the crystalline form agrees with that of specular iron. Its localities are numerous.

TITANIFEROUS CERITE. *Min.* A blackish-brown mineral with a vitreous lustre, and conchoidal fracture, from the Coromandel coast. It contains oxides of cerium, iron, titanium, with silica, lime, alumina and water.

TITANITE. See SPHENE.

TITANIUM. *Chem.* Menakan, Titan. Supposed to exist by Gregor in 1791; recognised by Klaproth in 1794. Mostly examined by Klaproth and Rose. It occurs in rutile, anatase and brookite with but little foreign matter; is a more or less abundant constituent in titaniferous iron and a few minerals; and is found in small quantity in many mineral substances.

1. *Titanium.* It is obtained as an incidental product in many iron-blast furnaces, slags, in cavities, and more frequently in the old hearth-

stones, which are often penetrated by metallic iron and titanium. From this source it is obtained by treatment with muriatic and then with nitro-muriatic acid; which leaves the titanium in the form of a copper-red powder, or in cubical crystals of spec. grav. 4.3. It has been found in an old hearth-stone at Duncannon Iron Works on the Susquehanna, below the mouth of the Juniata, and at Conshohocken furnace, on the Schuylkill, above Philadelphia. It is also obtained by heating titanfluoride of potassium with potassium, or chlortitanium-ammonia with or without sodium. It is generally in powder, of a red, violet, or black color, which last becomes red by pulverizing. In coarse powder it is not attacked by any of the common acids alone, nor by aqua regia with the aid of heat, but it is soluble in heated nitrofluohydric acid. It scarcely oxidizes in the air except by calcination, and by fusion with borax and saltpeter it is oxidized. Sym. Ti. Eq. 24 (24.12. H = 1, or 301.55. O = 100. *Berz.*)

2. *Titanic acid.* Titanic oxide. TiO_2 . It is always procured from rutile or titanic iron, from the latter of which in fine powder, a large portion of the iron may be first extracted by muriatic acid. The finely-powdered mineral is fused with carbonate of soda in a crucible, treated with water, which dissolves the alkali and leaves acid titanate of soda; it is washed on a filter until the liquid passes through cloudy, when it is removed from the filter, dissolved in strong muriatic acid, diluted with water, treated with sulpho-hydrogen, which throws down tin, (this is filtered off), poured into a flask, to which ammonia is added, and then corked; the precipitate is titanic acid, and sulphurets of iron and manganese; after settling, the clear liquor is drawn off by a syphon and must smell of sulphhydrate of ammonium, (if not, the latter must be added, and the solution again allowed to settle); a solution of sulphurous acid is poured over the residue in the flask, which dissolves all the sulphurets and not a trace of titanic acid, provided the sulphurous acid were in excess; the acid is washed on a filter. By igniting titanic iron with sulphur, sulphuret of iron is formed, which may be removed by muriatic acid, and by retreating the residue either by sulphur or in sulphuretted hydrogen, and by muriatic acid, titanic acid may be obtained free from iron.

Prop. A white, tasteless, infusible powder, becoming yellow by heat, but white again on cooling. When precipitated, it is soluble in acids, ^a TiO_2 , but by a gentle heat, water passes off, and at a much higher heat it undergoes a kind of ignition, and is insoluble in acids, ^b TiO_2 . The former is procured from the latter by ignition with alkali, solution in cold acid and precipitation; or by heating with oil of vitriol; or by mixing it with charcoal, and passing chlorine over it, when a soluble chloride distils over. The three native titanic acids, rutile, brookite, and anatase, seem to be three modifications of this acid.

From solutions the hydrate is precipitated by ammonia; it is white, gelatinous, soluble in acids, and slightly in carbonated alkalies. It is also precipitable by carbonated alkali, an excess of which redissolves a portion; yellow

prussiate of potash gives a reddish brown precipitate, soluble in excess of the precipitant; nut galls also give a brownish red precipitate.

Zinc, iron, and tin give to the acid solutions of titanic acid a blue or purple color, and then a similar powder, which changes in some days to titanic acid; this is probably sesquioxide of titanium = $\text{Ti}_2\text{O}_3 = \text{TiO}, \text{TiO}_2$.

A *protoxide*, TiO , appears to be formed by heating the acid in a charcoal crucible; it is black, insoluble in all acids, and difficult to oxidize to titanic acid.

3. *Bisulphuret of Ti.* TiS_2 is obtained by passing bisulphuret of carbon over titanic acid intensely ignited in a porcelain tube; it is dark-green with a brass-yellow streak. By igniting a mixture of 1 titanic acid, 1 sulphur, and $\frac{1}{2}$ coal, digesting and washing with water, then with oil of vitriol, a bronze yellow sulphuret is obtained.

By fusing phosphate of titanium with charcoal powder, Chenevix obtained a white, metallic, brittle phosphuret. Alloys of titanium have been but little examined.

4. *Chloride of Ti.* TiCl_2 , formed by passing chlorine over heated metallic titanium, or a mixture of powdered rutile and coal, is a clear, heavy liquid, boiling at 275° , with a strong acid odor, fuming in the air, forming a saline mass with a little water, dissolving in more water. The latter is also obtained by solution of the hydrated acid in muriatic acid; by evaporation, a portion is converted into titanic acid, and by sufficient heat, it loses all its muriatic acid. The dry chloride absorbs dry ammonia, becoming a red powder, 2NH_3 , TiCl_2 , which by ignition in a tube leaves metallic titanium, and evolves salammoniac with a yellow sublimate, which is a double chloride of titanium and ammonium, $3\text{NH}_4\text{Cl}$, 2TiCl_2 . Dry chloride absorbs phospho-hydrogen, forming a brown powder, which yields in a tube a yellow sublimate, PH_4Cl , 3TiCl_2 . By mixing chloride of titanium with chloride of sulphur, and exposure to cold, large yellow crystals are obtained, $x\text{TiCl}_2$, SCl_2 ; very soluble in water, and changing into titanic, muriatic, sulphuric, and dichionous acids.

5. *Fluoride of Ti.* TiF_2 . The dry compound is obtained by distilling fluor spar, titanic acid, and fuming sulphuric acid, as a colorless, fuming liquid. The hydrated salt is procured by dissolving the hydrated acid in fluohydric acid, and may be crystallized by evaporation. By solution in water it is resolved into an insoluble basic salt, and a soluble acid salt, which latter, is *titanfluohydric acid*, analogous to *silicofluohydric acid*; $\text{HF} + \text{TiF}_2$. This acid forms double salts with other fluorides, those of the alkalies, KF , TiF_2 , &c., being crystalline, and soluble in water without decomposition, those of lime and magnesia with decomposition. The ammoniacal salt leaves by heat in a platinum retort, NH_4F , 2TiF_2 .

6. *Oxysalts.* *Acid sulphate* is obtained by heating titanic acid with oil of vitriol until the excess of sulphuric is driven off, and dissolving in a little water; when diluted and heated, or by adding alcohol, a basic salt precipitates; another basic salt precipitates on adding sulphuric acid to a dilute muriatic solution. A sulphate of titanic oxide of potassa is obtained

TOADSTONE.

by dissolving titanic oxide in fusing bisulphate of potassa; water separates most of the titanic acid, and ammonia throws down the rest from the aqueous solution. A *nitrate* is obtained by solution of the hydrated oxide in nitric acid. Phosphoric acid throws down from the muriatic solution of the oxide a white *phosphate*, soluble in excess of the solution and of phosphoric acid. A white *phosphite* is obtained by dissolving terchloride of phosphorus in water, neutralizing with ammonia and adding it to a solution of chloride of titanium.

TOADSTONE. *Geol.* Earthy basalt.

TOBACCO. The dried leaves of the *Nicotiana Tabacum*, extensively employed for smoking, &c. Posselt and Reimann's analysis of the leaves give as their composition:—

Nicotin.....	0.060
Nicotianin.....	0.010
Bitter extractive.....	2.870
Gum and malate of lime.....	1.740
Green resin.....	0.267
Albumen.....	0.260
Gluten.....	1.048
Malic acid.....	0.540
Malate of ammonia.....	0.120
Sulphate of potassa.....	0.048
Chloride of potassium.....	0.063
Malate and nitrate of potassa.....	0.095
Phosphate of lime.....	0.166
Malate of lime.....	0.242
Silica.....	0.088
Lignin.....	4.969
Water.....	87.820
Starch.....	trace

The ashes of the plant contain—

(1) J. W. Jones. (2) A. S. Jones.

Silica.....	15.59	14.50
Lime.....	11.60	14.25
Magnesia.....	7.75	6.50
Potassa.....	7.30	8.40
Soda.....	2.50	2.75
Chloride of potassium..	1.75	1.80
Alumina and ox. } manganese }	4.50	3.20
Carbonic acid.....	19.75	18.00
Sulphuric acid.....	12.30	13.90
Phosphoric acid.....	14.80	15.00
Ammonia.....	2.00	1.50

No. 1 was a light tobacco, used for smoking, and No. 2 was grown on limed land. Barral, (*Comptes Rendus*, xxi. 1374), who examined a dozen different kinds of tobacco, states:—

That the quantity of ashes in all species averages, in round numbers, 7 pr. ct. for the roots, 10 for the stems, 22 for the branches, 23 for the leaves, and only 4 for the seeds.

That the composition of the ashes varies with the nature of the soil upon which the tobacco grew. The root contains about eight times as much silica as all the other parts of the plant, and the proportion is greater in the branches than in the leaves. The upper parts of the plant contain more lime than the root, and the proportion of potassa decreases from the stem upwards.

That tobacco is richer in nitrogen than any other plant, the quantity varying, however, in different varieties. It ranges from 5 to 6 pr. ct. in the leaves, and the branches contain only 1 to 1.5 pr. ct. less. In the seeds there is about

TOBACCO.

6 pr. ct. of nitrogen, and 10 pr. ct. of a colorless fat oil.

According to Goupil, tobacco also contains citric acid, and Barral has also announced the presence of *nicotic acid*.

Zeise, who examined the products of the dry distillation of tobacco, finds them constituted of *peculiar empyreumatic oil*, butyric, carbonic, and acetic (?) acids, ammonia, paraffin, resin, water, carbonic oxide, and carburetted hydrogen. Melseus (*Ann. de Chim. et de Phys.* ix.) also found nicotin.

Oil of Tobacco. Light brown, very poisonous, of an acrid taste, and of the odor of much-used tobacco pipes. When dehydrated over chloride of calcium and rectified, it boils at 284°, but its boiling point gradually reaches 572°, the color during the interval becoming yellow, green, and ultimately brown, the original odor being lost during the reaction.

Nicotic Acid. $C_6H_5O_3 + HO$, (Barral). Crystallizes in micaceous scales, soluble in water, forming an insoluble salt of lead, and crystallizable compounds with ammonia, nicotin, and potassa.

Nicotianin. The essence or odorant principle contains nitrogen, according to Barral. It is a fatty substance, obtained by distilling the leaves with water. According to Landerer, it does not exist in the fresh leaves, but is generated during their desiccation. It is volatile, soluble in alcohol and ether, but insoluble in water. By distillation with potassa, it yields, (Barral),—

Nicotin. Formula $C_{10}H_7N$, (Melsens and Schloesing); $C_{10}H_8N$, (*Örtigosa*); $C_{20}H_{14}N_2$, (Barral). A colorless, oily liquid, existing in tobacco, and readily extracted by Schloesing's process, (*Comptes Rendus*, 1846). It is a highly poisonous, powerful base, very soluble in ether, alcohol, and oils, decomposable by exposure to air and by the action of chlorine, iodine, and nitric acid. Spec. grav. 1.048. Boils and decomposes at 585°, but distils, unaltered, at a lower temperature. It is miscible with water, but separates on the addition of caustic potassa. The salts of nicotin are very soluble in water and alcohol, and difficultly crystallizable.

According to Schloesing, (*Chem. Gaz.* v. 43), the content of nicotin in the different tobaccos is as follows:—

Lot.....	7.96	—per cent. of the
Lot et Garonne.....	7.34	dried tobacco.
Nord.....	6.58	...
Ile et Vilaine.....	6.29	...
Pas de Calais.....	4.94	...
Alsatia.....	3.21	...
Virginia.....	6.87	...
Kentucky.....	6.09	...
Maryland.....	2.29	...
Havanna, less than.....	2.00	...

It will be seen from this table that those tobaccos which contain the most nicotin are also the best suited for the manufacture of snuff.

The above method of determining the amount of nicotin applied to snuff indicated as a mean 2.04 nicotin pr. ct. of the dried powder; whence it is concluded that about two-thirds of the nicotin contained in the mixed leaves destined for the manufacture of snuff is destroyed by the fermentation. The ammonia exists in the

snuff in the state of a salt; the nicotin, partly in a free state, and partly as a neutral salt, or altogether in the state of a subsalt. It is to these two salts that snuff owes its property of exciting the mucous membrane of the nose.

The similarity in composition, and many reactions between nicotin and anilin, induced Melsens to suggest the query whether the former might not be formed by the oxidation of the latter; but Barral has shown from the determination of the specific gravity of these vapors, (*Chem. Gaz.* v. 445), each calculated according to $C_{10}H_7N$, that of nicotin extends to 2 vols., and that of anilin to 4 vols.; hence, as the formula must be doubled, all analogies disappear.

In the action of nicotin upon protochloride of platinum two new compounds are formed: 1. An orange-colored salt, $Pt + Cl, C_{10}H_7N, 2 KCl$; 2. A red salt, $Pt + Cl, C_{10}H_7N, KCl$, (*Racuzky*). Nicotin gives, by digestion and distillation with potassa, an agreeably smelling, oily fluid, which forms with bichloride of platinum a very soluble salt in yellow scales.

TOLEN. See TOLU BALSAM.

TOLU BALSAM. The balsamic, concrete exudation of the *Myrospermum toluiferum*. It consists, according to Kopp, of free cinnamic acid, $C_{18}H_{13}O_4$, tolen, and two resins.

Tolen. $C_{10}H_8$. A pungent, colorless fluid, of spec. grav. 0.858 at 50° , and boiling at $309-320^\circ$.

Alpha Resin. $C_{36}H_{19}O_8$. Brown, translucent, brittle, and shining when cold. Fuses at 140° , and by dry distillation yields benzoen and benzoic acid. Dissolves readily in alcohol and ether. Its solution in caustic potassa decreases on exposure.

Beta Resin. $C_{36}H_{20}O_{10}$. Dull yellowish brown, tasteless, and inodorous, slightly soluble in alcohol and ether. Sulphuric acid colors it violet red, and the alpha resin purple.

Tolulole. Syn. Benzoën. $C_{14}H_8$. A product of the destructive distillation of the balsam. With nitric acid it forms nitrotoluide, (*proto-nitrobenzoen*), $C_{14}NH_7O_4$, a liquid, analogous to nitrobenzide, which, when placed in vapor over red hot lime, is converted into anilin, $C_{12}NH_7$, and carbonic acid. By the successive action of alcoholic ammonia and sulphuretted hydrogen it is converted into sulphur and a new artificial base.

Toluidin. $C_{14}H_9N$, (*Muspratt and Hoffman*). A transparent, colorless, crystalline mass, of the exact taste and smell of anilin, soluble in alcohol, ether, pyroxylic spirit, acetone, sulphuret of carbon, the fixed and essential oils, and slightly in water. Fuses at 104° and boils at 388° . Belongs to the same class of bodies as anilin, and like it forms with most acids readily crystallizable compounds. Its acid solution imparts an intense yellow color to fir-wood and elder pith, but it does not, like anilin, give a deep, beautiful blue with chloride of lime.

TOLUIDIN. See TOLU BALSAM.

TOMBAC. See ALLOY.

TOMBACITE. *Min.* An arsenical nickel; described by Breithaupt, but not minutely examined.

TONKA BEAN. The pod containing the seed of the *Dipterix odorata* of Willd. and the *Coumarouna odorata* of Aublet, a large tree growing in Guiana. It contains a colorless fat oil,

soluble in ether, but insoluble in water and in alcohol, and has an agreeable aromatic odor, which is due to its active constituent.

Coumarin exists also in other plants, among which are the *Melilotus officinalis* and *Anthoxanthum odoratum*. To extract it, the sliced beans are macerated in cold alcohol of 0.848, and the liquor distilled. The syrupy residue, on cooling, drops small yellow prisms of coumarin, which may be purified by recrystallization.

Prop. Composition, $C_{10}H_8O_2$ (*Henry*); $C_{18}H_7O_4$ (*Delalande*); $C_{18}H_6O_4$ (*Bleibtreu*). A concrete volatile oil, or stearopten, forming white crystals of greater spec. grav. than water, fusing at 122° , and boiling at 518° , apparently unaltered. Hot water dissolves it more readily than cold, and drops it in needles on cooling. In ether and alcohol it is very soluble. Dissolves also in warm potassa solution, but is reprecipitated unaltered by acids.

Coumaric acid. $C_{18}H_{15}O_5$, HO, (*Delalande*). Obtained by boiling coumarin in very strong potassa solution, and precipitating the liquor with HCl acid. The coumaric acid falls in bright lamellæ. During the reaction of the potassa, salicylic acid is also a product, but Bleibtreu did not observe any evolution of hydrogen, as Delalande had noted. To free the crystals of salicylic acid, they must be washed; and to separate traces of undecomposed coumarin, dissolved in aqua ammoniæ, and boiled until the complete expulsion of the volatile alkali. The acid is then precipitated with nitrate of silver, and the salt washed successively with water, alcohol and ether. The decomposition of the salt by HCl acid yields the acid which may be taken up by ether. The ethereal solution being evaporated and then treated with water, drops the coumaric acid in crystals.

It dissolves readily in alcohol, ether, and water, and does not produce the least coloration with the persalts of iron (*Bleibtreu*). At 374° it fuses, and above that temperature decomposes in part into a brown resin and oil, and sublimates in brilliant white crystals.

Nitrocoumarin. $C_{18}H_5NO_4$, O_4 . (*Bleibtreu*). Formed by dissolving coumarin in cold fuming nitric acid, and treating the solution with excess of water. If the mixture be heated, picric acid is formed. It crystallizes in silky, white needles, which are soluble in boiling water, alcohol, and ether. At 338° it sublimes unaltered into pearly white crystals.

The transformation of coumarin into salicylic and carbazotic acids establishes its relation to salicyl.

TOPAZ. *Min.* Pyenite, Schorlite, Physalite, Pyrophysalite. Cryst. Right rhombic; vertical prisms often striated, and terminated by 8-hedral planes and an end-plane; also granular. $H.=8$. $G.=3.4-3.65$. Yellow, white, green, blue, red; vitreous; transparent, subtranslucent; fracture subconchoidal, uneven. Infusible; difficultly soluble in fluxes, leaving silica in mic. salt, and opalizing; with a little soda, half fusible, with more, infusible; fused with soda and roasted in an open tube, it shows traces of fluoric acid. Decomposed by ignition with alkali, and partially by heating with sulphuric acid. Formula for topaz pro-

posed by Rammelsberg from Forchhammer's late analyses $(\text{Al}_2\text{F}_3 + \text{SiF}_3) + 2(\text{Al}_2\text{O}_3, \text{SiO}_3 + 2\text{Al}_2\text{O}_3, \text{SiO}_3)$, and of Pycnite $(\text{Al}_2\text{F}_3 + \text{SiF}_3) + 3(\text{Al}_2\text{O}_3, \text{SiO}_3) + 2\text{Al}_2\text{O}_3, \text{SiO}_3$. The first member may be viewed as $\text{Al}_2\text{O}_3 + \text{SiO}_3$, in which oxygen is replaced by fluorine. It occurs in primary rocks in many localities in Europe, but in the United States, only at Trumbull and Middletown, Connecticut.

False Topaz. See QUARTZ. *Oriental Topaz.* See CORUNDUM.

TOPAZOLITE. See GARNET.

TOURMALIN. *Min.* Turmalin, Schorl, Rubellite, Indicolite, Aphrizite. Cryst. Hexagonal, usually prismatic (sometimes rounded by the number of planes) and terminated by a flat rhomb. $H. = 7-8$. $G. = 3.02-3.08$. Color, black, brown, blue, green, red, rarely white; sometimes red internally and green externally; sometimes many colors in the same crystal; also dichroic; lustre vitreous; transparent, opaque; brittle, with subconchoidal, uneven fracture, and white streak. Their behavior varies; some fuse to a slag, others only swell up; the black sometimes burns white, at others it does not; some give the reactions of iron and manganese; all show boracic acid, with fluor spar and bi-sulphate of potassa. It is impossible to give a correct formula at present for tourmalin, which consists of silica, boracic (carbonic) acid, alumina, oxides of iron and manganese, magnesia, lime, lithia, soda, potassa. Tourmalin has been divided into four groups, according as the alkalies and magnesia predominate. Hermann divides them from his late examination into Schorl (black, brown, green), Achroite (colorless), and Rubellite (red), and including carbonic acid in his formula, and writing both boracic and silicic, $\text{BO}_2, \text{SiO}_2$. The localities of tourmalin are numerous.

TRACHYTE. *Geol.* A gray feldspathic rock, of little lustre. When studded with crystals of feldspar, it is a trachytic porphyry. Berthier's analysis of one from Dept. Puy de Dome makes it a feldspar; Abich's, of one from Transylvania, gives $12\frac{1}{2}$ pr. ct. of matter decomposable by acid, consisting of magnetic iron and glassy feldspar, and the rest of albite, containing soda, potassa, and lime.

TRAGACANTH. The gummy exudation of the *Astragalus tragacantha* of Crete. Spec. grav. 1.384. Swells in water, and forms an adhesive paste without dissolving. Is entirely insoluble in alcohol. It consists of several components.

1. *Traganthin*. Adraganthin, (53 pr. ct.) This is the *arabin* portion soluble in water, but giving no precipitate with silicate of potassa or sesquichloride of iron.

2. *Bassorin*, (33 pr. ct.). (See GUMS); 3. *Insoluble starch*; 4. Water. The ashes amount to 2.5 pr. ct.

TRAIN OIL. The train oil of the beaked whale (*Balena rostrata*) is far better suited for purposes of illumination than the ordinary train oil. It burns with a flame of intense brilliancy, becomes turbid at 46° , and forms a crystalline paste a few degrees above 32° . According to Scharling, (*Journ. für Prakt. Chem.* xliii. p. 257), it consists principally of a very liquid fat, containing no glycerin, with traces

of spermaceti and other fats; and appears to be a compound of an acid with a base. Thus admitting the composition of the oil as required by analysis to be $\text{C}_{62}\text{H}_{60}\text{O}_4$, we have

New acid..... = $\text{C}_{38}\text{H}_{35}\text{O}_3$

New base..... = $\text{C}_{24}\text{H}_{25}\text{O}$.

TRAP. *Geol.* A name given to a class of intrusive rocks, which are sometimes very hard, tough and crystalline, at others soft and earthy. The crystalline usually consists of a feldspar and hornblende, the latter rendering it darker in proportion to its quantity. Trap embraces Diorite, Greenstone, and Hypersthene rocks.

TRASS. *Geol.* A natural cement, or volcanic ash. Ilgner's analysis of one variety gives 49 pr. ct. decomposed by muriatic acid, 43 undecomposed and $7\frac{1}{2}$ pr. ct. ammoniacal water. The undecomposed contains 87 pr. ct. silica; the decomposed 23 silica, 36 alumina, 24 oxide of iron, 11 lime and magnesia, and $5\frac{1}{2}$ soda and potassa.

TRAVERTINE. See CALCAREOUS SPAR.

TREACLE. See SUGAR.

TREMOLITE. See HORNBLLENDE.

TRIGENIC ACID. *Chem.* Formed by the action of cyanic acid upon aldehyde. (*Liebig and Wöhler*). Crystallizes in radiately-grouped prisms, difficultly soluble in water and insoluble in alcohol. The silver salt is a white powder, (soluble in hot water), which by exposure to light becomes violet. By heat it yields quinolin. (*Liebig's Annalen*, lix. p. 291.)

TRICLASITE. See FAHLUNITE.

TRIPHAN. See SPODUMEN.

TRIPHYLIN. *Min.* Triplite, Pitchy Iron-ore, Tetraphylin, Perovskin. Cryst. Right rhombic, with one perfect cleavage, and two others imperfect; usually massive. $H. = 5-5.5$. $G. = 3.44-3.77$. Greenish gray, yellowish, bluish, brown, subject to tarnish; resinous; translucent, opaque; streak gray, yellowish gray.

Behavior. Triphylin yields water; fuses readily to a steel-gray, magnetic globule, coloring the flame bluish green, especially after moistening with oil of vitriol; shows with the fluxes, iron and manganese. Tetraphylin behaves similarly, but gives a strong manganese reaction; with boracic acid and iron it shows phosphoric acid. Triplite gives traces of fluoric acid in an open tube and shows manganese in borax. They dissolve readily in acids, and are mostly decomposed by potassa-lye. Form. of triphylin, $3\text{RO}, \text{PO}_5$, in which $\text{RO} = \text{FeO}$, MnO , LiO , (Triplite = $4\text{RO}, \text{PO}_5$). But Fuchs observed that triplite is only disintegrated triphylin, containing peroxide of iron and manganese, no lithia, and 5 pr. ct. water. Triphylin is from Bodenmais; tetraphylin from Finnland; triplite from Bodenmais, Limoges, and from Washington, Connecticut. See HETEROZITE, HURAUITE.

TRIPOLI. *Geol.* A deposit almost wholly consisting of siliceous shells of animalculæ, the silica amounting to 80 pr. ct. It is used for polishing.

TRONA. *Min.* Urao. Cryst. Oblique rhombic; also fibrous. $H. = 2.5-3$. $G. = 2.11$. Grayish or yellowish white; vitreous, glistening; translucent; taste alkaline; does not effloresce in dry air. Fuses in its crystalline water; gives a yellow soda-flame; dissolves in

water, and has alkaline reaction. Form. 2NaO , $3\text{CO}_2 + 4\text{HO} = \text{sesquicarbonate of soda}$. From Maracaibo, S. A.

TROOSTITE. *Min.* Tephroite. Cryst. Hexagonal, the prism terminated by rhombs; perfect hexagonal cleavage; also massive and granular. $\text{H.} = 5.5$. $\text{G.} = 3.01-3.03$. Dull asparagus-green, yellow, gray, reddish brown; vitreous; transparent, translucent; brittle, with conchoidal fracture and white streak. Imperfectly fusible; shows manganese with borax; effervesces with muriatic acid and evolves some chlorine. Form. 3FeO , $2\text{SiO}_3 + 3(3\text{MnO}, \text{SiO}_3)$ (?) with 7 pr. ct. carbonate of manganese. With Franklinite at Sterling, N. Jersey.

TRUFFLES. (*Tuber cibarium.*) See FUNGI.

TSANTJAN. *Syn.* Kanten. A preparation of the *Fucus cartilaginosa*, (*Siebold*), used in Japan as a substitute for the edible birds' nests, and exported to China as an article of commerce. It has the form of twisted isinglass, of a yellowish white color, and is used in the form of jelly. It probably contains pectin and pectates. *Bley*.

TSCHEWKINITE. *Min.* Massive. $\text{H.} = 4-4.5$. $\text{G.} = 4.508-4.549$. Velvet-black; sub-translucent, opaque, edges brown by transmitted light; fracture flat conchoidal. It exhibits phosphorescence by heat, swells, becomes brown, and fuses to a black bead; yields water in a tube; shows iron and silica with the fluxes, and manganese with soda. The difficulties of analysis prevent the establishment of a formula; it contains silica, titanate acid, oxides of cerium, lanthanum, didymium, iron and manganese, &c. From the Ilmengebirg.

TUESITE. *Min.* See HALOYLITE.

TUFA. *Geol.* A volcanic, earthy rock. See TRASS.

TUGGHADA. *Syn.* Chew resin. A new resin found in the cavities of *Pinus abies*, in Noorland, and so called because the country people chew it. It is brittle, but softens between the teeth and develops a balsamic odor and acid taste, and ultimately becomes pink.

By distillation, it yields a dark yellow essence, entirely different from the oil of terpentine. By boiling with water, an acid is taken up, and, on cooling, crystallizes out in red granules. The earthy and alkaline salts of this acid are yellow, soluble in water and in alcohol but insoluble in ether and not crystallizable. (*Berlin, Annuaire de Chimie*, 1845, p. 371.)

TUNGSTATE OF LEAD. *Min.* Cryst. Quadratic. $\text{H.} = 2.75-3.0$. $\text{G.} = 7.904-8.088$. Green, gray, brown, red; streak white; subtranslucent. It fuses, giving off vapors of lead which coat the coal, and leaving a dark, submetallic, crystalline globule, gives with mic. salt a colorless glass in the outer, a blue in the inner flame, soluble in nitric acid, leaving yellow tungstic acid. Form. PbO , WO_3 . From Zinnwald, Bohemia.

TUNGSTEN. See SCHEELITE.

TUNGSTEN. *Chem.* Wolframium, Scheelium. Tungstic acid was discovered by Scheele in 1781, de Luyart obtained the metal, and Berzelius chiefly investigated its properties. It is a rare metal, and occurs in few minerals, as in Tungsten, Wolfram, Tungstate of lead, &c.

1. *Tungsten.* Obtained by reducing tungstic acid by the most powerful ignition with charcoal; or by hydrogen at a high heat; or by hydrogen at a lower heat, when the acid contains a little potassa. It is between steel-gray and silver-white, very hard and brittle, spec. grav. 17.5: burns to tungstic acid by ignition in the air, and forms the same by nitromuriatic acid. *Sym. W.* (Wolframium). $\text{Eq.} = 95$. (1188-36. $\text{O} = 100$. *Berz.*)

2. *Oxygen. a. Binoxide of Tu.* WO_2 , obtained by evaporating tungstate of potassa with excess of salammoniac to dryness, igniting in a crucible, extracting chloride of potassium by water, and unaltered tungstate of potassa by boiling with dilute potassa; a black powder. It is also obtained by acting on tungstic acid by zinc and dilute muriatic acid, which are renewed until the whole is changed into copper-red laminae, washing with water apart from the air, and keeping under water. By ignition with carbonate of soda it is converted into tungstate of soda and metallic tungsten.

b. Blue oxide. $\text{W}_2\text{O}_5 = \text{WO}_2$, WO_3 , is obtained by heating tungstate of ammonia in a tube until it assumes a dark blue color, or by passing hydrogen or carbonic oxide over the heated acid.

c. Tungstic acid. WO_3 . Obtained from the mineral Wolfram (Tungstic iron), by digesting the fine powder repeatedly with muriatic acid, to which a little nitric is added towards the last to peroxidize iron, until the brown powder has passed into yellow, washing well with water, then treating the residue with ammonia, which dissolves out tungstic acid, evaporating the filtered solution to dryness, or to crystallization, and ignition in the air, by which tungstic acid remains. Wolfram may also be fused with 2 pts. carbonate of soda or potassa, boiled with water, the hot liquid treated with salammoniac, evaporated to dryness, and ignited, as in preparing binoxide, above given. By fusion of Wolfram with 2 pts. chloride of calcium, and extraction of the powdered mass with boiling water, tungstate of lime remains, which, as well as the mineral tungstate of lime is treated with nitric or muriatic acid to separate tungstic acid. The dry acid is a yellow powder, scarcely soluble in muriatic and in fluoric acid, reduced by heat with carbon, or hydrogen, or by many organic bodies to a lower oxide or to metal. A hydrate is obtained by supersaturating a hot very dilute solution of tungstate of potassa by warm nitric acid, when the gelatinous hydrate separates after some time. When tungstic acid is precipitated by an acid, it retains a portion of the precipitant.

Tungstates. The tungstates of alkali and magnesia are soluble in water, all are insoluble in alcohol; muriatic, sulphuric, and nitric acids decompose the tungstates, separating part as tungstic acid and part as a compound with the decomposing acid. Solutions of the alkaline tungstates give a white precipitate with sulphuric, muriatic, nitric, phosphoric and acetic acids, insoluble in their excess, except in the phosphoric; oxalic, tartaric and citric give no precipitate; the addition of bi-sulphuret of ammonium and then of muriatic acid gives a precipitate of tersulphuret of tungsten; salts of the alkaline earths and metals throw down

tungstates of these bodies from the alkaline tungstates.

2. *Tungstate of potassa.* a. The neutral salt is obtained by digesting tungstic acid with a due proportion of potassa, and evaporating. The crystals are soluble in 1 pt. cold, $\frac{1}{2}$ pt. hot water, with the form. $\text{KO}, \text{WO}_3 + 5 \text{HO}$.

b. *Bitungstate.* Dissolve tungstic acid to saturation in a boiling solution of caustic, carbonated or tungstic potassa, and filter hot. The crystalline powder is permanent in air, fusible, soluble in 100 pts. cold, $8\frac{1}{2}$ pts. boiling water, and, like the former, precipitable by acids; form. $\text{KO}, 2 \text{WO}_3 + 2 \text{HO}$. The neutral soda salt has the composition $\text{NaO}, \text{WO}_3 + 2 \text{HO}$, and the acid salt $\text{NaO}, 2 \text{WO}_3 + 4 \text{HO}$. The neutral salt of ammonia loses ammonia by evaporation and the bi-salt crystallizes with the form. $\text{NH}_4\text{O}, 2 \text{WO}_3 + \text{HO}$. The neutral salt of magnesia is soluble, those of baryta, &c., the earths and metals insoluble. The acid salts of baryta and strontia are crystallizable.

Tungstate of tungstic oxide and soda, $\text{NaO}, \text{WO}_3 + \text{WO}_2, \text{WO}_3$, obtained by passing dry hydrogen over heated bitungstate of soda as long as water forms, and extracting neutral tungstate of soda by water, forms golden yellow, metallic, cubes and powder; decomposable by heat in the air into tungstate of soda (and tungstic acid?). The potassa salt yields copper-red needles, resembling sublimed indigo.

3. *Sulphur.* a. *Bisulphuret*, WS_2 , obtained by powerfully igniting 1 pt. tungstic acid with 6 pts. vermilion, is a grayish black powder, lustrous by friction. b. *Tersulphuret*, WS_3 , obtained by dissolving tungstic acid in bisulphuret of potassium, or saturating tungstate of ammonia by sulphohydrogen, precipitating by an acid, and washing, is a black or brown powder, slightly soluble in water, (reprecipitable by acids or salammoniac), soluble in caustic alkali, with formation of alkaline tungstate, and sulphotungstate, soluble in alkaline sulphides. *Sulphotungstates*, in which the tersulphuret is the acid, and another sulphide the base, have the form. MS, WS_3 ; the alkaline are red, crystallizable, soluble; the others obtained by double decomposition with the alkaline.

4. *Bichloride of tungsten.* WCl_2 , metallic tungsten, heated in chlorine, forms bichloride, partly in fine needles, and partly fused, sublimes in red vapor; decomposed by water, forming binoxide and muriatic acid; by alkali, forming tungstate and muriate of ammonia, and evolving hydrogen. *Terchloride*, WCl_3 , made by passing chlorine over bisulphuret, and subliming from one bulb to another through a series of 5 bulbs, forms transparent red needles, decomposable by water and in the air into tungstic and muriatic acids. When oxide of tungsten is heated in a stream of chlorine, tungstic acid remains, and an oxychloride sublimes in yellowish white scales, sublimable without fusion, decomposable by water into tungstic and muriatic acids. Its formula is $\text{WCl}_3 + 2 \text{WO}_3$, and Berzelius terms it Biachloride of Tungsten. A similar biaci-bromide of tungsten is obtained by heating the oxide strongly in bromine; $\text{WBr}_3 + 2 \text{WO}_3$.

5. *Fluoride of tungsten* is obtained by dissolving tungstic acid in fluohydric acid, and may be evaporated to dryness. It decomposes with

water, leaving a basic fluoride, while the solution contains tungsto-fluohydric acid. The potassa salt of this acid, obtained by adding potassa to it, until a permanent precipitate appears, forms large crystals, permanent in air, soluble in hot water. Form. $\text{KF}, \text{WF}_3 + \text{KO}, \text{WO}_3$. The similar soda salt is more soluble in water.

TUNGSTIC ACID. *Min.* Bright yellow, earthy tungstic acid, WO_3 , at Lane's mine, Monroe, Connecticut.

TURF. *Geol.* The semifossilized remains of plants, often used as fuel, and in one part of Denmark so rich in resin as to be used for light. Forchhammer's examination of a resin found near Holtegaard, in Denmark, gives *Tekoretin*, almost insoluble in alcohol, fusing at 113° , boiling at 689° ; soluble in ether. Form. $\text{C}_{20}\text{H}_{18}$. *Phylloretin*, crystallizing from its alcoholic solution, fusible at 188° , boiling at 689° . Form. $\text{C}_{40}\text{H}_{25}$. When turf-wood is extracted by alcohol, evaporated to an extract, and treated with ether, the solution deposits *Xylloretin*, which when crystallized is composed of $\text{C}_{40}\text{H}_{34}\text{O}_4$, combines with bases, fuses at 329° . The portion insoluble in ether contains *Boloretin*, composed of $\text{C}_{40}\text{H}_{33}\text{O}_3$, difficultly soluble in alcohol, readily in ether, apparently an indifferent body. Forchhammer found the last also in the fresh leaves and twigs of fir-trees, in retinasphalt, and in amber.

TURMALIN. See TOURMALIN.

TURMERIC. *Chem. Tech.* The root of the *Curcuma longa* and *rotunda*, much used as a dye-stuff. It contains lignin, starch, gum, an odorant, acid, volatile oil, a brown coloring matter, and—

Curcumin. The yellow coloring principle, extracted by alcohol and ether. Is in the form of a brown, resinous mass, which gives an inodorous, tasteless, yellow powder, soluble in alcohol, ether, and the oils, but nearly insoluble in water. Fuses at 104° , and bleaches by exposure to the sun. Alkalies change it to a brown, and hence paper soaked in a solution of it is used as a test of alkalinity; but as strong mineral acids, many metallic salts, and alcoholic solution of boracic acid change it to red, or brownish red, according to Berzelius, its indications are not reliable.

TURNERITE. *Min.* Pictite. Cryst. Oblique rhombic. H. above 4. Yellow or brown, adamantine, transparent, translucent, streak white, or grayish. According to Children, it consists chiefly of alumina, lime, and magnesia, with but little iron and silica. From Mt. Sorel, Dauphiné.

TURNSOLE. See LITMUS.

TURPENTINE. See TERPENTINE.

TURPETH MINERAL. The subsulphate of MERCURY.

TURQUOISE. See CALAITE.

TUTENAG. The Indian name for ZINC; sometimes applied to the alloy known as "*Chinese copper*."

TWIN CRYSTALS. See CRYSTALLOGRAPHY.

TYROSIN. One of the products of the decomposition of casein. $\text{C}_{16}\text{NH}_9\text{O}_5$ (*Liebig*.) Crystallizes in fine needles, sparingly soluble in cold water, and insoluble in alcohol and ether. It dissolves in alkalies, but combines with acids.

U.

ULMIC ACID, } See MOULD.
ULMIN.

ULTRAMARINE. *Min.* See HAUYNE. *Tech.*
A beautiful, blue pigment, formerly obtained by grinding the lapis lazuli. The mineral has been repeatedly and carefully analyzed, and as its composition appeared to be simple, repeated attempts were made to produce it artificially, which have resulted in success. It is prepared from alumina, sulphuret of sodium, and copperas. For the alumina, the purest white clay is taken, as free from iron as possible, and very rich in alumina. It is washed over and passed through fine sieves, the last slip being allowed to deposit, and the deposit kept in a moist state. The sulphuret of sodium is prepared by moistening the best salt-cake, (from the manufacture of carbonate of soda), heating it in a furnace to remove every trace of free acid, mixing 100 pts. of this dry sulphate with 33 pts. best charcoal and 10 pts. fine lime, all in fine powder, reducing the mixture in a reverberatory, extracting the sulphuret by water, boiling the clear solution with powdered sulphur, to make the pentasulphuret, (100 pts. fused sulphuret require 40—50 sulphur), and concentrating it until it is 1.2, (25° B.), when it contains 25 pr. ct. dry sulphuret. To make the blue, 100 lb. of the sulphuret solution, (= 10½ galls.), are evaporated rapidly to a syrup, 25 lb. of the dry clay stirred in, (or so much of the moist as contains this quantity), and during the stirring ½ lb. of pure cryst. copperas added, and the whole intimately mixed. It is then evaporated to dryness, during constant stirring, and reduced rapidly to a fine powder. The powder is heated in a layer of 3 inches depth in a muffle to a gentle red heat, and maintained at that heat for ¾ to 1 hour, while it is frequently stirred. When cold, it is washed with water, until all the saline matter is extracted, dried, powdered, sifted, and again heated in a separate muffle, (10—15 lb. at a time), to a moderate red heat for ½ to ¾ of an hour, and when the blue color begins to appear, it is raked until a fine deep is attained. It is then ground fine, and washed over to obtain different degrees of fineness. (*C. P. Prückner.*) For further details of this interesting manufacture, see *Chem. Gaz.* iii. 288, and a still more detailed account in *Journ. für Prak. Chem.* Nov. 1844.

UMBELLIC ACID. *Chem.* A product of the oxidation of the essence of aniseed, star essence and fennel, by chromic acid. Formula $C_{16}H_{14}O_5 + Aq.$ (*Hempel.*) Crystallizes in colorless needles. Its silver salt is in white, lustrous laminæ. According to Hempel, it is identical with anisic and dragonic acids.

UMBER. An earthy body, containing, according to an analysis by Maus,—

Sesquioxide of iron.....	46.2
Oxide of manganese.....	9.8
Silica	33.1
Water.....	10.5

It is used as a pigment, and as a drier of paints and varnishes.

UPAS POISON. See ANTIARIN.

URALITE. The crystalline form is augite, with the cleavage of hornblende.

URAL-ORTHITE. See ORTHITE.

URAMIL. See URIC ACID.

URANIC OCHRE. *Min.* A yellow, earthy coating on uranium-ore; either hydrated or carbonated oxide.

URANITE. *Min.* Uran-mica, Uranphylite, Lime-uranite, Chalcolite, Copper-uranite. Cryst. Quadratic, with many 8-hedra, with a perfect cleavage parallel to the end-plane. Lustre of end-plane pearly, of the rest adamantine, transparent, subtranslucent, sectile, lamina, brittle. Form. of uranite $3 RO, PO_5 + 2 (3 U_2O_3, PO_5) + 24 HO$. The RO in the first is CaO with a little BaO, in chalcolite it is CuO. There are two sub-species, lime and copper-uranites.

1. Lime-uranite. H. = 2—2.5. G. = 3.05—3.19. Yellow and greenish. 2. Copper-uranite or chalcolite. H. = 2—2.5. G. = 3.5—3.6. Emerald and other bright greens, with a paler streak. Both yield water in a tube, becoming yellow, fuse on coal with effervescence to a black bead with crystalline surface, dissolve in the fluxes with a yellow color in the outer and a green in the inner flame; but chalcolite gives the reaction of copper by adding tin to the bead of mic. salt; both form a yellow, infusible slag with soda, the chalcolite giving reduced copper. *Local.* Autun, Limoges, Cornwall, &c. In the U. S. Middletown, Conn.; Chesterfield, Mass.; Chester on the Delaware River.

URANIUM. *Chem.* Discovered by Klaproth, in 1789, as an oxide; the metal was first obtained in 1841, by Peligot. It occurs in larger quantities in pitchblende or uranium ore, and in smaller quantities in some other minerals.

1. *Uranium.* The metal is obtained by quickly putting alternate layers of potassium and dry chloride of uranium into a platinum or iron crucible, binding the cover on by wire, and heating. After the violent combustion which ensues, it is again heated to volatilize the excess of potassium and fuse its chloride, so that the metal may agglutinate. The cooled mass is dissolved out by water, which leaves uranium. Wöhler's method is to evaporate the muriatic solution of the uranic oxide-ammonia, with an excess of salammoniac and about an equal quantity of common salt to dryness, to heat it in a closed crucible to volatilize the salammoniac, and fuse the common salt, and extract the cooled mass by cold water. A black crystalline or amorphous powder, which may be kept unaltered under pure water, but by the slightest quantity of acid it oxidizes rapidly with evolution of hydrogen. When heated, it burns rapidly in the air to green oxide. Sym. U. Eq. = 60 (59.43 H = 1; 742.875 O = 1. *Ebelmen.*)

2. *Oxide of Uranium, UO.* Obtained by heating the green oxide in hydrogen, or with ⅓ of charcoal, or by igniting the oxalate apart from the air. It is an iron-gray or reddish brown powder. The hydrate is obtained of a reddish brown color by precipitating an oxide salt by caustic alkali. It forms green salts, which oxidize readily in the air by nitric acid, are precipitable by alkalies and carbonate of lime, resolvable in carbonate of ammonia.

3. *Oxide-sesquioxide.* Green oxide. $U_3O_4 = UO + U_2O_3$. It is obtained from uranium ore or pitchblende, which contains 50—90 pr. ct.

of it, together with many other substances, by solution in nitromuriatic acid, passing sulphohydrogen through it, warming it slightly and filtering, whereby silica, sulphur, arsenic, antimony, copper, bismuth, lead, tin, and silver are removed. The filtrate is heated with nitric acid to peroxidize iron and uranium, precipitated by ammonia, washed, and the precipitate treated by carbonate of ammonia, which dissolves all the uranium and portions of zinc, nickel, cobalt, and lime. The solution is evaporated to volatilize the ammonia, and the uranium, after washing and drying, is ignited in a platinum crucible to convert it into green oxide. By digestion with muriatic acid, the green oxide remains, while uranates of lime, nickel, &c., are dissolved. It is a dark green or black powder, soluble by digestion in a close vessel in strong muriatic or sulphuric with a green color. Digestion with nitric acid changes into a peroxide salt. The green solution, precipitated by ammonia, yields a grayish green hydrate of oxide-sesquioxide. Ammonia dissolves out peroxide from the fresh hydrate, and leaves brown hydrated oxide.

4. *Sesquioxide*. Uranic acid. U_2O_3 . The hydrate is obtained by dissolving green oxide in nitric acid, evaporating to dryness, keeping it fused in a low heat until nitric acid ceases to pass off, and boiling in water until nothing more dissolves. It is a gold or orange-yellow powder, which by careful heating loses the greater part of its water, becoming brick-red, and at a higher heat all its water and a portion of oxygen. Its salts with acids are yellow, generally soluble, and contain 1 eq. oxide to one of acid; reducible by sulphohydrogen, several metals and other bodies to a lower oxide; precipitable of a brownish black by sulphide of ammonium, after standing some time; yellow by the alkalis, insoluble in their excess, by the carbonated alkalis, soluble in their excess, especially in acid carbonates, by carbonate of lime, alkaline oxalate, succinate, and phosphate; brown by tincture of galls, and brownish red by yellow prussiate of potash. Its combinations with bases may be termed uranates, and when precipitated by the alkalis, these accompany it, as well as when mixed with metallic salts and precipitated by ammonia.

5. *Sulphuret*, US , is made by introducing the metal into the vapor of sulphur, or by passing bisulphuret of carbon over ignited green oxide. Yellowish black, readily attacked by nitric acid.

SALTS.

1. *Haloid Salts*. a. *Chloride of U*. UCl . Make an intimate mixture of green oxide of uranium and $\frac{1}{2}$ charcoal, adding a little sugar to them, heat the mixture in a crucible to char the sugar, break it thin into lumps, put these in a very infusible glass, pass dry chlorine slowly over it while it is gently heated, then more chlorine with a higher heat. The chloride sublimes and condenses in the tube, as dark-green, metallic 8-hedra, which sublime by heat with a red vapor; it is very soluble in water and liable to oxidation. By passing dry hydrogen over the heated chloride, it is resolved into a dark-brown, crystalline, soluble mass, of the form. $U_4Cl_3 = U_2Cl + 2 UCl$.

By passing chlorine over the ignited oxide

of uranium, orange-yellow vapors form, which condense as a yellow, crystalline, fusible body, very soluble in water, alcohol, and ether, of the form. $2 UO, Cl$, or, according to Berzelius, basic perchloride, (Uran-biäci-chlorid), $U_2Cl_3 + 2 U_2O_3$. This compound is also obtained by solution of the peroxide in muriatic acid, and evaporation to a syrup, when it will crystallize in a dry air. It forms double salts with alkaline chlorides, those with potassium and ammonium being crystallizable; form. $3 KCl + U_2Cl_3, 2 U_2O_3 + 6 HO$.

b. *Bromide*, UBr , is obtained by dissolving the hydrated oxide in bromhydric acid and evaporating, as green crystals with 4 HO , very soluble and decomposable. By dissolving the peroxide in the same acid an oxybromide is formed, of a yellow color, and with form. $U_2Br_3 + 2 U_2O_3 + aq$. A similar solution in iodhydric acid yields black crystals of oxidide.

c. *Oxyfluoride* is obtained in the same way by fluohydric acid, uncrystallizable, forming yellow double salts with alkaline fluorides. Silicofluoride, $3 UF + 2 SiF_3 + aq$, is obtained as a bluish green precipitate, by adding silicofluohydric acid to a solution of chloride.

2. *Salts of Oxide*. a. *Sulphate* is formed by dissolving green oxide in excess of oil of vitriol, adding a little water and alcohol, and exposing it to sun-light, when it forms green crystals on the sides of the glass, with the form. $UO, SO_3 + 2 HO$. By adding sulphuric acid to the protochloride, green crystals are obtained with 4 HO . Both are permanent in the air when dry, water extracts an acid salt, which rapidly passes into a persalt and leaves a basic salt, as a light green powder, of the composition $2 UO, SO_3 + 2 HO$. It forms green, crystallizable double salts with the alkaline sulphates. Sulphite of soda added to a solution of protochloride, gives a grayish green precipitate of basic sulphite, $2 UO, SO_2 + 2 HO$.

b. *Chlorate and Perchlorate* are only known in solution, and rapidly oxidize. *Iodate and periodate* are grayish green, oxidable precipitates.

c. *Phosphate*, obtained from phosphate of soda and chloride of uranium, is a gelatinous, green precipitate, very insoluble, even in dilute acids, almost wholly decomposable by potassa, and of the composition $2 UO, PO_5 + 3 HO$. *Borate* is grayish green, from which water extracts all the acid.

3. *Salts of Sesquioxide*. a. $\frac{1}{2}$ *Sulphate* is obtained by dissolving oxide, or green oxide, in a little nitric acid, mixed with sulphuric, evaporating to dryness, driving off the excess of acid, dissolving in water, and evaporating to a syrup, when it sometimes crystallizes with the form. $U_2O_3, SO_3 + 3 HO$, or $U_2O_3, 3 SO_3 + 2 U_2O_3 + 9 HO$, soluble in water and alcohol. A $\frac{2}{3}$ sulphate is obtained by dissolving the preceding in a large excess of sulphuric acid, and letting it evaporate spontaneously; form. $U_2O_3, 2 SO_3 = 2 (U_2O_3, 3 SO_3) + U_2O_3$. Neutral sulphate is obtained by dissolving either of the above in boiling oil of vitriol, when it separates, on cooling, in yellow crystals, with the form. $U_2O_3, 3 SO_3$. The $\frac{1}{2}$ basic salt forms double salts with the alkaline sulphates, those of potassa having the composition $KO, SO_3 + U_2O_3, SO_3 + 2 HO$, and $2 (KO, SO_3 + 3 (U_2O_3, SO_3) + HO$.

URANIUM ORE.

b. $\frac{1}{3}$ Nitrate forms large crystals, very soluble in water, alcohol, and ether, with the form. $U_2O_3, NO_3 + 6 HO$, and appears to become a more basic salt by heat.

c. Phosphate, U_2O_3, PO_5 , is a pale-yellow precipitate, soluble in phosphoric acid, from which solution ammonia precipitates a more basic salt, $2 U_2O_3, PO_5$. Perphosphate of uranium and lime, or copper. See URANITE. Borate is a pale-yellow precipitate.

d. Iodate is a yellow precipitate, insoluble in water, scarcely soluble in nitric acid, and has the form. $U_2O_3, IO_5 + 5 HO$. Bromate is uncrystallizable, and the chloric salts have not been examined.

e. Carbonate is unknown, but its double salts with alkaline carbonates are crystallizable. By precipitating pernitrate by carbonate of potassa, dissolving it while moist in bicarbonate of potassa to saturation, and gently evaporating, it forms a bright yellow, crystalline crust. The ammoniacal salt is similarly obtained by carbonate and sesquicarbonate of ammonia on cooling the warm solution.

4. Uranates. Uranate of potassa is obtained as an orange powder, by adding a persalt to an excess of potassa, or by fusing the oxide with excess of potassa, and extracting alkali with water; form. $KO, 2 U_2O_3$. The uranates of potassa and soda are also obtained by igniting the double salt of peracetate of uranium and potassa; the latter is yellow, and has the same composition as that of potassa. The salt of ammonia is obtained as a yellow powder by adding a persalt to an excess of ammonia, insoluble in water, containing salammoniac. By igniting the double acetate of uranium and lime or magnesia, similar double salts are obtained, the former orange-yellow, the latter yellowish brown.

URANIUM ORE. *Min.* Pitchblende, Uranpecherz. Massive. $H. = 5.5$. $G. = 6.468$. Black, brownish, grayish, submetallic, dull; opaque; conchoidal fracture. Infusible; dissolves in the fluxes with a yellow color in the outer, and green in the inner flame; soluble by heat in nitric and nitromuriatic acid. Form. UO, U_2O_3 . From Schneeberg, &c., Saxony; Příbram, &c., Bohemia.

URAN-MICA. See URANITE.

URANONIOBITE. *Min.* Uranotantalite, Uranocolumbite, Samarskite, Yttrilmenite (?). Crystalline grains. $H. = 5.5$. $G. = 5.617-5.68$. Hermann's Yttrilmenite = $5.398-5.45$. Lustre submetallic, shining; opaque; streak dark reddish brown. Decrepitates in a tube and becomes blackish brown; on coal fuses on the edges to a black glass; in borax gives a yellowish green in the outer, a yellow to greenish black in the inner flame; in mic. salt gives an emerald green unaltered in the inner flame. Most perfectly decomposed by fusion with bisulphate of potassa. It contains about 56 pr. ct. niobic and tungstic acids, 16 protoxide of iron, 16 oxide of uranium and 10 yttria. From the Ilmengebirg. Hermann asserts his Yttrilmenite to contain an element Ilmenium.

URANPHYLLITE. See URANITE.

URAN VITRIOL. See JOHANNITE.

URAO. See TRONA.

UREA. *Chem. Syn.* Anomalous cyanate

UREA.

of ammonia. Exists in the solid portion of the URINE, of which it forms 30 to 50 pr. ct., according to the nature of the food and the state of the system or power of assimilation. The proportion is also modified by disease, augmenting with inflammation, and decreasing in those afflictions in which the blood is deficient in quantity or poor in corpuscles. In certain diseases, the urea, while in the urine, becomes partially transformed into carbonate of ammonia. Urea has been found in the blood, and in the vitreous humor of the eye, in sweat, in saliva, and in milk. It has been detected also in the serum of the blood, in Bright's disease, in cholera, diabetes, and in dropsical fluids. It is likewise a constituent of bile and biliary concretions, and of the liquor amnii. Is produced by the oxidation of uric acid.

Prep. 1. By evaporating urine to *syrupy* consistence, and, when cold, treating it with an equal volume of nitric acid of density 1.42. Nitrate of urea forms in a thick crystalline mass, which must be washed with dilute nitric acid, in which it is insoluble, then pressed between bibulous paper, dried, redissolved in warm water, and neutralized with carbonate of lead. The residue, after evaporation, when treated with alcohol, yields a solution of urea, which, after the removal of lead by sulphuretted hydrogen, and of color by animal charcoal, crystallizes out on concentration of the liquid.

2. Urea is prepared artificially by heating to dull redness, on an iron plate, a thorough mixture of 28 parts of dry ferrocyanide of potassium and 14 of peroxide of manganese. When the resultant brown mass is cold, it is to be repeatedly digested in cold water, and the solution mixed with 20.5 parts of crystallized sulphate of ammonia dissolved in water. Sulphate of potassa and cyanate of ammonia are formed, and on application of slight heat the latter is converted into urea. The fluid is therefore to be evaporated to dryness, over a water bath, and the mass heated with a small portion of water. The aqueous solution, on evaporation to dryness, yields sulphate of potassa and urea, which may be separated by alcohol of 90°, which dissolves only the urea and drops it again in crystals, on evaporation. From 5—6 ozs. of urea may be obtained from the above proportions. Clemm (*Ann. der Chem. und Pharm.* lxi. p. 382) gives another process, less simple than the above, by which a larger product may be obtained.

Prop. Formula $C_2H_4N_2O_2$. Crystallizes in white, transparent, silky needles; or in flat four-sided prisms, of spec. grav. 1.35. Deliquesces in moist air without change of chemical properties. Slightly soluble in ether; and readily so in water and in alcohol. A concentrated aqueous solution withstands lengthened exposure and even boiling without alteration, but the presence of albumen or ferment transforms it into carbonate of ammonia: metallic salts do not precipitate its solution in water.

A temperature of 250° melts urea, but a higher heat transforms it into ammonia, cyanate of ammonia, and dry solid cyanuric acid. Liebig and Wöhler found among the products of its decomposition by heat, a substance of the composition $C_{12}H_8N_6O_4$; and Wiedemann detected another, which he calls *Biuret*, $(C_4H_5$

N_3O_4). It is neutral, crystallizable and soluble in water and in alcohol. It is intensely reddened on the addition of caustic potassa and solution of sulphate of copper. It dissolves also in sulphuric acid, unaltered.

Salts. *Nitrate.* Formula $C_2H_4N_2O_2 + NO_5 + HO$, or according to Marchand, $C_2H_4N_2O_2 + 2NO_5, HO$. Crystallizes in shining scales or in opaque prisms, which are efflorescent. Soluble in water, and insoluble in nitric acid. At 316° decomposes and gives off carbonic acid, nitrous oxide, nitrate of ammonia and free urea remaining. During this reaction there is also formed, according to Pelouze, a new acid ($C_2H_3N_2O_4$) in grayish crystallized plates, which are soluble in water.

Muriate. An unstable compound, which at 293° gives off chloride of ammonium. The residual mass yields cyanuric acid to water. (*De Vry.*)

Oxalate. Formula $C_2H_4N_2O_2 + C_2O_3 + HO$. Crystallizes in plates or prisms. Slightly soluble in water and less so in alcohol.

URETHAN. See ETHYL.

URTHYLAN. See METHYL.

URIC ACID. *Chem. Syn.* Lithic acid, Uricic acid. Is a constituent of urinary and gouty concretions. It exists also in the excrements of birds and of serpents, and has likewise been found in the human saliva and perspiration.

Prep. By dissolving the excrement of the boa-constrictor in a boiling caustic potassa solution, filtering and adding hydrochloric acid in excess. The uric acid set free drops as a gelatinous mass, which, when well washed with cold water and dried in the air, becomes a crystalline powder. Bensch (*Ann. der Chem. und Pharm.* lvii. 266) prepares it from guano by boiling it for several hours with potassa, lime, and water, and filtering. The filtrate is then evaporated to a thick paste and pressed in a linen bag, and the contents of the bag diffused in water, and decomposed by hydrochloric acid. The uric acid thus thrown down is converted into urate of potassa, and reprecipitated, and by this means purified. The product equals $2\frac{1}{2}$ pr. ct.

Prop. Crystallizes in brilliant white, micaceous lamellae, of composition $C_5N_2HO_2 + HO$. Liebig thinks that it consists of urea and an hypothetical substance, which he calls *Uril* (*U*), or cyanoxalic acid: thus, $2\text{U} + 1\text{eq. urea}$ ($C_2H_4N_2O_2$). Is tasteless and inodorous, insoluble in alcohol and ether, and but slightly in water. Dissolves readily in solution of caustic potassa and in alkaline fluids generally, but not in solutions of bicarbonate of potassa or of ammonia. It is taken up by solutions of phosphate of soda and of borax.

When treated with nitric acid it effervesces and leaves a brick-red residuum by drying, which on the addition of a little ammonia turns deep violet, and this behavior is characteristic. Dilute nitric acid, after prolonged action, generates a series of new products, and ultimately oxalic acid. Oxidizing bodies generally produce the same results.

Salts. *Urate of Potassa* (neutral). Forms crystals of composition $KO, C_5N_2HO_2$. Soluble in 44 pts. cold, and 35 of boiling water. The acid salt, $KO, 2(C_5N_2HO_2) + HO$, insoluble in alcohol and ether, dissolves in 790 pts. of cold,

and 75 pts. of hot water. The soda salts are still less soluble in water.

There are no neutral salts of ammonia and magnesia. The bi-urate of ammonia requires 1600 of cold water for its solution, and the magnesia salt 3750 pts.

Urate of Lime. Soluble in 1500 pts. of cold, and in 1440 of hot water. The bi-salt requires only 603 of hot, and 276 of cold water for its solution. Allen and Bensch.

Metamorphosis of Uric acid. The permanency of uric acid, under ordinary circumstances, is disturbed by the action of powerful oxidizing agents, which generate a series of new products:—

1. UREA.

2. *Allantoin.* Syn. Allantoic acid, Amniotic acid. One pt. of acid boiled in 20 of water, and treated with fresh peroxide of lead, yields on filtration a liquid which drops transparent, glassy, rhombic prisms of allantoin. It occurs also, ready formed, in the allantoin fluid of the calf. Formula $C_4N_2H_3O_3$. Dissolves in alcohol, and in 160 pts. cold, and less of hot water. Is converted by caustic alkalies into ammonia and oxalic acid.

3. *Alloxan.* Syn. Erythric acid. Prepared by gradually adding 4 pts. of nitric acid of spec. grav. 1.45, to 1 pt. of dry uric acid. The resulting liquid soon crystallizes into a mass of alloxan. Composition $C_8H_3N_2O_{10}$. Soluble in water and in alcohol, and drops therefrom, by spontaneous evaporation, in brilliant, colorless octahedra. Its solution stains the skin purple. When heated, alloxan becomes anhydrous, and, on cooling, crystallizes in oblique rhombic prisms.

4. *Alloxantin.* Form. $C_8H_5N_2O_{10}$. Obtained by treating uric acid with cold, dilute nitric acid. Also results from the action of sulphuretted hydrogen upon alloxan, in the earlier stage of the process.

5. *Parabanic acid.* Formula $C_6N_2O_4 + 2HO$. Results from the action of 8 pts. of nitric acid upon 1 pt. of uric acid or of alloxan. Crystallizes colorless, and partially sublimes when heated. Soluble in water, and when neutralized in warm solution by ammonia, the liquid on cooling drops crystals of oxalurate of ammonia. This latter salt, when decomposed by hydrochloric acid, yields—

6. *Oxaluric acid.* Formula $C_6N_2H_3O_7 + HO$. A crystalline powder, which by long boiling with water is transformed into oxalate of urea and free oxalic acid.

7. *Murexid.* Syn. Purpurate of ammonia. Formula $C_{12}H_6N_5O_8$ (*Liebig and Wöhler*), or $C_{16}H_8N_6O_{11}$ (*Fritzsche*). Prepared by warming uric acid together with dilute nitric acid, and when it reaches a flesh color and has cooled to 160° , by adding weak ammonia in slight excess. The liquid is then diluted with half its bulk of water. Short, 4-sided prisms drop from the liquid on cooling. They are deep red by transmitted, and metallic-green by reflected light. Its aqueous solution is purple. In caustic potassa it is soluble with a blue color, which disappears on the application of heat, ammonia being evolved. Is insoluble in alcohol and ether. When the potassa solution is treated with dilute sulphuric acid, it precipitates—

8. *Murexan.* Syn. Purpuric acid. Formula

$C_6H_4N_2O_5$ (*Liebig* and *Wöhler*), or $C_{16}H_4N_5O_{10}$ (*Fritzsche*). Crystallizes in yellow, silky scales, insoluble in water and in dilute acids. Strong sulphuric acid dissolves and yields it unaltered upon the addition of water.

9. *Alloxanic acid*. Produced by the action of baryta water upon a concentrated solution of alloxan. The resultant salt of baryta, when decomposed by sulphuric acid, yields crystals of alloxanic acid, of composition $C_8H_2N_2O_8 + 2HO$. Is bibasic and isomeric with alloxan. The formula of its salts is $C_8H_2N_2O_8, 2RO + Aq$.

10. *Mesoxalic acid*. Obtained by precipitating a solution of alloxan with a boiling solution of acetate of lead, and decomposing the salt. Forms sour crystals, of the composition $C_3O_4 + 2HO$ (?).

11. *Mycmelinic acid*. Formula $C_8H_5N_4O_5$. Prepared by heating a solution of alloxan with ammonia, and decomposing the yellowish, gelatinous salt with dilute sulphuric acid. A very acid powder, slightly soluble in hot, and less so in cold water. Its silver salt is yellow, and insoluble in water.

12. *Thionuric acid*. Formula $C_4H_7N_3O_{14}S_2$. Obtained by treating alloxan with sulphurous acid or solution of a sulphite, and boiling. The crystals of ammonia salt which form on cooling, are converted into a lead compound which, on addition of sulphuric acid, yields thionuric acid. Is bi-basic, soluble, and crystallizable. When its solution is heated, it becomes cloudy, and drops—

13. *Uramil*. Formula $C_8H_5N_3O_6$. Is in crystalline powder or feathery scales, soluble in ammonia and in potassa; the solution absorbs oxygen, becomes purple, and deposits green crystals of potassium—murexid. When heated with dilute sulphuric acid, it yields—

14. *Uramitic acid*. Formula $C_{16}H_{10}N_6O_{15}$. Crystallizes in fine prisms, very soluble in water.

15. *Dialuric acid*. Formula $C_8H_3N_2O_8$. Obtained in the latter part of the reaction, when alloxan is treated with sulphuretted hydrogen. Crystallizes, and is soluble in water. By exposure its solution absorbs oxygen, and becomes alloxantin. Forms sparingly soluble salts, which are permanent only when dry.

In addition to the foregoing, there are other products of the decomposition of uric acid, of which several have been mentioned and described by Schlieper (*Liebig's Annalen*, 1845).

16. *Leucoturic acid*. Formed with *Difluon*, by heating alloxanic acid or its solution to ebullition, and rapidly evaporating the solution. Formula $C_6H_3N_2O_6$ (*Schlieper*). A snow-white, crystalline powder, soluble in hot, but insoluble in cold water. Readily soluble in alkalies, and may be re-precipitated by acids, if the solution is recent and cold. Its characteristic property is its resistance to the action of acids.

17. *Difluon*. Formula $C_6H_4N_2O_5$. A white, loose powder, which fuses at 212° , and is very deliquescent. When dried, it becomes transparent and brittle.

18. *Hydusilic acid*. A product of the imperfect oxidation of uric acid, and existing in the mother liquor filtered from the impure alloxan as obtained by Schlieper's process (*Chem. Gaz.* iv. pp. 1 and 99). Formula $C_{15}H_5N_3O_{11}$. A white, loose powder, composed of slender needles,

soluble in hot water and in alkalies, but insoluble in alcohol, and nearly so in cold water. Forms both acid and neutral salts with the bases. The composition of the silver salt is $2AgO, C_{12}H_3N_3O_9$.

19. *Allitric acid*. Formula $C_6N_2H_2O_3 + HO$. Formed by evaporating a solution of alloxantin with excess of muriatic acid. A yellowish, crystalline powder, soluble in boiling water and in strong sulphuric acid. Water precipitates it from the latter, unaltered. Hot nitric acid produces no change. Potassa dissolves, and at the same time decomposes it.

20. *Dilituric acid*. Exists in combination with ammonia, to which, as well as to other bases, it adheres with obstinate tenacity. Is bibasic, and of the composition $C_8N_3HO_8 + 2Aq$. The ammonia salt, $C_8N_3HO_8, NH_4O + HO$, is in brilliant yellow laminae, soluble in hot water.

URINARY CALCULI. *Chem. Physiol.* Morbid concretions of the crystallizable matters of the urine, resulting from a deranged action of the system. They are round, oval, polygonal, or cylindrical, according to the location or origin, and they vary in color from yellow, red dish brown, to dirty green. Their density ranges from 1.213—1.975, and their weight from a few grains to 50 ozs. Their internal structure is uniform, or else in concentric layers, formed around a nucleus of the same ingredients as the calculus, or mucus, blood, or some foreign matter introduced into the bladder. The components vary with the disease and state of the system, and occur more or less frequently, as to proportion, in order as follows:—

Uric Acid, urate of ammonia, oxalate of lime, neutral and basic phosphate of lime, ammonia-magnesian phosphate, urate of soda, urate of magnesia, urate of lime, benzoate or hippurate of ammonia, oxalate of lime, uric or xanthic oxide, cystin, carbonate of lime, carbonate of magnesia, fibrin, silica, urostealith, albumen, mucus, perox. iron, fibrin, cholesterolin, and extractive matters.

Urinary calculi are styled, according to their composition, as follows:—

1. Calculi of uric acid,
2. " " urate of ammonia,
3. " " uric or xanthic oxide,
4. " " cystin,
5. Fibrinous or protein calculi,
6. Calculi of carbonate of lime,
7. " " phosphate of ammonia and magnesia, and of phosphate of lime,
8. " " neutral phosphate of lime,
9. " " carbonate of lime,
10. " " urostealith.

Simon (*Chem. of Man*) has given a full description of each, with directions for distinguishing them.

Uric or Xanthic Oxide. Syn. Urous acid. A rare ingredient of guano and of calculi, in the latter of which it is united with but a small portion of animal matter. Formula $C_5N_2H_2O_2$. Dissolves in nitric acid, which on evaporation leaves it as a yellow residue. It is precipitated by acids from its potassa solution, as a white powder. Is partially soluble in hot water, but insoluble in alcohol, ether, and solution of car-

bonate of potassa. Its solution in sulphuric acid is not precipitated by water.

Cystin. Syn. Cystic oxide. Formula $C_6NH_6O_4S_2$. Frequently forms the sole ingredient of a calculus. Crystallizes in 6-sided, colorless, transparent scales. Is soluble in alkalis and in acids, forming with the latter crystalline compounds. Insoluble in water and in alcohol. Burns with a bluish flame, and emits a peculiar odor, which is characteristic.

Urostealite. Discovered by Heller (*Chem. Gaz.* iii. 468). Soluble in carbonate of soda and in ether. Softens in water without dissolving, and is taken up slowly by hot alcohol. Its solution in nitric acid is colorless, but by evaporation leaves a residue which on treatment with ammonia or potassa becomes dark yellow.

When heated, it emits the odor of benzoin and shellac, and if ignited, burns with a clear yellow flame, or leaves an ash principally of lime.

URINE. *Chem. Physiol.* The animal excrementitious fluid secreted by the cortical portion of the kidneys, and thence flowing into the bladder, from which it is ejected by the contraction of the attached muscles, through the urethra. Its average spec. grav. is 1012.5.

Urine recently excreted by a healthy person is transparent, of a straw-yellow color, with a peculiar odor, which disappears as the urine loses its warmth, which is that of the mean temperature of the body. Prout, Spangeberg, Simon, and others, mention abnormal urines of a blue color; Dulk's one of a black, and Velsen another of a violet hue. The physical and chemical characters present modifications varying with the nature of the food and the pathological state of the system.

Urine consists, according to Marchand and Lehman, of—

	1.	2.
Water.....	933-199	938-856
Solid residue.....	66-801	61-144
Urea	32-675	30-321
Uric acid.....	1-065	1-001
Lactic acid.....	1-521	1-362
Extractive.....	11-151	10-553
Mucus.....	.283	.201
Sulphate of potassa	3-587	3-201
“ “ soda	3-213	3-011
Phosphate of soda	3-056	2-998
Bi-phosphate of ammonia.....	1-552	1-231
Chloride of sodium.....	4-218	4-001
“ “ ammonium	1-652	1-231
Phosphates of lime and magnesia	1-210	1-001
Lactates.....	1-618	1-032

The amount of water often fluctuates. The yellow coloring matter of normal urine is due to the presence of *Hæmapharin*, and the red color to *Uroerythrin*. Heller has announced the presence, in healthy urine, of another pigment, *Uroxanthin*, which by oxidation is transformed into a ruby-red matter, *Urrhoidin*, and one of a blue tint, *Uroglauclin*. The strong castor odor and deep color of inspissated urine, is attributed by Scharling to a brown, organic matter, which he calls the oxide of a new radical, termed *Omichmyl*. In addition to these constituents, there have been described two

unnamed new acids, by Pettinkofer and Heintzig; and carbonic, fluoric, and hippuric acids, and creatin are also components.

According to Simon and others, bodily exercise augments the amount of urea and of sulphates. The amount of urea is also increased by an excess of nitrogenous food, and vice versa.

If the system becomes unhealthy, then the nature of the urine changes, and includes in its composition abnormal constituents, viz., albumen, sugar, carbonate of ammonia and of lime, pus, fibrin, fat, cystin, and the ingredients of the blood. The urinary deposits known as **URINARY CALCULI** are morbid secretions.

Healthy urine is not precipitated by acids, though oxalic acid produces a cloudiness. Free alkalies throw down phosphate of lime. The mucus separates in slight nebulae after long standing, and by continued exposure the urine emits an unpleasant odor, and carbonate of ammonia is formed, which by precipitating the phosphate of lime and ammonio-magnesian phosphate, causes turbidity. By still further exposure the urine becomes concentrated, and drops its saline constituents in crystals.

For information in detail, see the very elaborate and able article in *Simon's "Chemistry of Man."*

UROERYTHRIN. } See URINE.

UROGLAUCIN. }

UROSTEALITE. See URINARY CALCULI.

UROXANTHIN. } See URINE.

URRHOIDIN. }

URYL. *Chem.* Syn. Cyanoxalic acid. Symbol, $\overline{U}$. The assumed radical of uric acid, and certain of its derivatives. It contains the elements of 2 eqs. oxalyl (C_2O_2) and 2 eqs. of cyanogen ($2 C_2N$) = $C_8N_2O_4$, the formula for *uryl*.

USNIC ACID. See LICHENS.

UVAROVITE. See GARNET.

V.

VACCINIC ACID. *Chem.* Found by Lerch in BUTTER, and intermediate in composition between caproic and butyric acids. It is not a constant constituent. (*Chem. Gaz.* ii. 381.)

VALENCIANITE. *Min.* It is a FELDSPAR.

VALERACETONITRIL. See GELATIN.

VALERIAN. *Chem. Pharm.* The root of the *Valeriana officinalis*. Trommsdorff's analysis gives as its composition—Volatile oil 1.2, peculiar extractive, (soluble in water and insoluble in ether and alcohol), 1.25; gum 18.75; soft odorant resin 6.25; lignin 63. The active principle of the plant is its essential oil, which contains a peculiar volatile acid, the—

Valerianic. Syn. Phocenic acid. Exists likewise in the bark and berries of the *Viburnum opulus*. Is also a product of the action of potassa upon oil of potato spirit (see *AMYL*), and upon CASEIN. Is formed, too, by the putrefaction of casein, and by the action of potassa and sulphuric acid upon oil of chamomile, of chromic acid upon GELATIN, and of nitric acid upon OLEIN. According to Löwig, valerianic acid exists in valerian, combined with glycerin, forming a peculiar fat.

Prep. Righini proposes the following method:—20 lbs. of wild valerian root are taken, (collected in the month of October or November), and after having washed them with water and cut them in very small pieces, they are piled up in a marble mortar, adding enough water to remove all the juice by means of pressure. The juice thus obtained is placed in a small pan, and heated nearly to the boiling-point; carbonate of lime in very fine powder, or lime water, is then added; valerianate of lime is precipitated, and after repose for 2–3 hours, water acidulated with muriatic acid is added to the precipitate. The latter, combining with the lime, gives rise to the production of chloride of calcium, and sets free the valerianic acid. The whole is exposed to a gentle heat; and after continuing the evaporation until a pellicle commences to be formed, the liquid is introduced into a retort, and distilled in a sand-bath to remove the valerianic acid, whilst the chloride of calcium remains in the retort. The distillation should be carried to dryness. The quantity of root mentioned above yielded by this process 160 grms. of very pure valerianic acid. (*Journ. de Chim. Méd.* July, 1845.)

Prop. A pale yellow, limpid, inflammable oil, of strong penetrating odor and acrid taste. Spec. grav. 0.944; boils at 270°; dissolves in alcohol, ether, spirits of turpentine, and in 26 pts. of water. When a strong solution of any of its salts is decomposed by an acid, the valerianic becomes $\overline{\text{Va}}$, 3 HO.

According to Kolbe (*Chem. Gaz.* v. 227), when subjected as valerianate of potassa to a voltaic current, it is resolved into hydrogen, carbonic acid, a new gaseous hydro-carbon, C_8H_8 , an ethereal oil consisting partly of C_8H_9 and carbonate of potassa. This chemist views valerianic acid as a conjugate compound of the radical C_8H_9 with oxalic acid.

Valerianate of oxide of Ethyl. AeO , Va . An oily liquid, with a penetrating odor. Spec. grav. 894. *Otto*.

Valerianate of Zinc. Prepared by digesting 1 pt. of freshly precipitated carbonate of zinc in 2 pts. of valerianic acid, dissolved in 360 pts. of water. On filtering and cooling, pearly scales are deposited. Dissolves in 160 pts. of water and 60 pts. of alcohol, of .833. According to Laragne and Hurant (*Journ. de Pharm.* 1846), much of this salt, found in commerce, under this name, is *butyrate* of zinc, which resembles it closely in physical properties.

Valerianate of Iron. Formula $3 \text{Fe}_2\text{O}_3 + 7 \text{Va} + 2 \text{HO}$. An amorphous red powder.

Valerianate of Baryta. Form. $\text{BaO} + \text{C}_{10}\text{H}_9\text{O}_3$. Crystallizes in minute white prisms, of great lustre, and readily soluble in water. By distillation above 662°, it yields *Valeral* or *Valerianic aldehyde*, $\text{C}_{10}\text{H}_{10}\text{O}_2$, (*Chancel*). A clear, colorless fluid; boiling at 230°; insoluble in water, but soluble in alcohol, ether, and the essential oils, and of spec. grav. 820° at 72°. (*Comptes Rendus*, xxi.)

VALERIANIC ACID. See VALERIAN.

VALERONITRIL. See GELATIN.

VALONIA. The acorn of the *Quercus aegilops* from the Levant. The dry extract gave no trace of pyrogallic acid by distillation. *Stenhouse*.

VANADATE OF COPPER. *Min.* An earthy coating, and reniform masses, with lamellar structure, of a lemon-yellow color, and pearly lustre; from the eastern slope of the Ural.

VANADATE OF LIME. *Min.* It probably exists in URANIUM ORE.

VANADINE-BRONZITE. *Min.* Schafhaeutil analyzed a bronzite containing vanadic oxide.

VANADINITE. *Min.* Vanadate of lead, Vanadinbleierz. Cryst. Hexagonal, generally in incrustations. H. = 2.75. G. = 6.662–7.23. Yellow, reddish-brown, subtranslucent, opaque, brittle with white or yellowish streak. It decrepitates violently, fuses on coal with emission of sparks to a globule of lead, and coats the coal; soluble in mic. salt with a yellow color in the outer, and green in the inner flame; decomposed by nitric, muriatic, and sulphuric acids. Form. of that from Zimapan, 2PbO , $\text{VO}_3 + (\text{PbCl}, 2 \text{PbO})$. It was first found in 1801 at Zimapan, in Mexico, by Del Rio, and has since been found at Wanlockhead, Scotland, and at Beresow.

VANADIUM. *Chem.* Del Rio found a metallic acid in 1801, in a brown lead ore from Zimapan, in Mexico, which he thought new, and termed the metal erythronium. Collet Discotil's assertion that it was chromic acid was received by Del Rio. Sefström found a new metal upon dissolving some Swedish iron, which he termed vanadium, and which Wöhler showed to be identical with Del Rio's erythronium. It has been chiefly studied by Berzelius. It occurs in small quantity, as vanadate of lead, also in some iron and copper ores, and in uranium ore.

1. *Vanadium.* Obtained by heating vanadic acid powerfully in a charcoal crucible, or by a lower heat in a porcelain crucible mixed with potassium; or lastly, by heating the terchloride, charged with dry ammonia, in a current of dry ammonia. Silver-white, or black, metallic, oxidized readily by heating in the air, and by nitric or nitromuriatic acids. Sym. V. Eq. 68.55 (856.89 O = 100 *Berz.*)

2. *Oxides, a. Suboxide of V.* VO . Obtained by reducing vanadic acid in hydrogen at a red heat; is black, infusible, a better negative electromotor than copper, gold, or platinum, decomposed when heated in chlorine into terchloride and vanadic acid; it combines neither with acid nor base.

b. *Oxide of V.* Vanadous acid. VO_2 . The hydrate is obtained by freeing a blue vanadium solution from vanadic acid by sulpho-hydrogen, sugar, or alcohol, precipitating by carbonate of soda in slight excess, washing, drying rapidly in paper, and then in vacuo. It is light brownish gray, and when ignited in vacuo loses water, and becomes the black, dry oxide. Its salts, with acids, are brown or green when dry, blue when in solution; precipitable brown by caustic alkali; grayish white by carbonated alkali; yellow by yellow prussiate; and yellowish green by red prussiate of potash; bluish black by infusion of galls; blackish brown by sulphide of ammonium, soluble with a purplish colour in an excess of the precipitant. It also acts as an acid, combining with bases to form vanadites, those of the alkalies being made by direct solution, and the others by precipitation; they are dark brown or black, readily

oxidized to vanadates in the air, changed to blue by acids, to purplish red by sulphohydrogen.

c. Vanadic acid. VO_3 . Obtained 1. from uranium ore (pitchblende), by fusing it with an equal quantity of saltpeter and carbonate of soda, dissolving out by boiling water, neutralizing exactly by nitric acid (free from red fumes), precipitating by chloride of barium or acetate of lead, decomposing the precipitate by boiling with dilute sulphuric acid, neutralizing the yellow filtrate by ammonia, and precipitating vanadate of ammonia by putting a piece of salammuniac into the liquid. 2. From vanadate of lead by dissolving in nitric acid, precipitating by sulphohydrogen, heating the blue filtrate, evaporating the clear liquid to dryness by a gentle heat, boiling the red residue with carbonate of ammonia, and filtering hot, when the vanadate of ammonia crystallizes out, and may be purified by recrystallization. By heating vanadate of ammonia nearly to ignition in an open crucible, with frequent stirring, dark red vanadic acid remains. It is fusible, and congeals to a yellowish red, crystalline mass, with a brick-red powder, soluble in 1000 pts. of water, with an acid reaction, insoluble in absolute alcohol. It dissolves in acids to yellow or red solutions, which leave red or yellow compounds, sometimes crystallizes, upon evaporation. By dust, organic acid, sugar, alcohol, &c., the solutions are reduced to a lower oxide; sulphhydrate of ammonium gives a brown precipitate, soluble in an excess of the same; alkalies a brown, soluble in an excess with a yellow or brown color. It forms neutral and acid salts with bases. Both are yellow, but some of the neutral are also obtained colorless, generally soluble in water, not in alcohol; they give orange precipitates with salts of lead, copper, mercury, and antimony.

d. Vanadates of V. 1. Purple. When the hydrated oxide, *b.* is exposed in a loosely closed bottle for 24 hours, and water poured on, it becomes green; this is washed with water on a filter, until a purple solution passes through, which is probably a basic vanadate of the oxide. 2. The oxide dried in the air, and digested with a little water, becomes the green oxide, which dissolves in water, with a blackish green colour. It is also obtained by mixing a neutral salt of the oxide with a neutral alkaline vanadate in solution, or by fusing the oxide and acid in equivalent proportions; its formula is $\text{VO}_2, 2 \text{VO}_3$. 3. Bivanadate, $\text{VO}_2, 4 \text{VO}_3$, is obtained of a green color, by mixing a neutral oxide-salt with an alkaline bivanadate; it is more perfectly precipitated by salammuniac. 4. The orange-colored oxide is obtained by exposing a solution containing more than 1 pr. ct. oxide to the air, when it passes from green, through yellow to orange.

3. *Sulphurets.* *a. Bisulphuret.* Sulphovanadous acid. VS_2 . Obtained dry, by passing sulphohydrogen over the ignited oxide, is black, insoluble in muriatic and sulphuric acids, and in caustic alkali. The alkaline sulphhydrates give rich purple solutions, with the salts of the oxide, from which acids throw down the brown sulphuret, soluble in alkalies and sulphhydrates, with a purple, in alkaline carbonates with a brown color. The sulpho-

vanadites of the alkalies are purple and soluble, those of the alkaline earths reddish brown, and less soluble.

b. Tersulphuret. Sulphovanadic acid. VS_3 . Obtained by dissolving vanadic acid in sulphhydrate of ammonium, and precipitating by an acid, is brown-white, moist, black when dry, soluble in caustic; carbonated and sulphuretted alkalies with a brown color. The sulphovanadates of the alkalies are reddish brown in solution, those of the alkaline earths darker, and less soluble; all others insoluble.

4. *Phosphuret* is obtained by strongly igniting the phosphate with a little sugar; a black, porous mass. Vanadium forms brittle alloys with the metals, which have not been minutely studied.

5. *Haloid salts.* Vanadic acid dissolves in muriatic acid with evolution of chlorine, but to reduce the acid wholly to oxide, the liquid is digested with vanadium, or its protoxide, or with alcohol, sugar, &c. It is a blue solution of *bichloride*, which, by evaporation, leaves a brown basic salt. When oxide of vanadium, obtained by ignition of vanadate of ammonia in a close crucible, is dissolved in heated and strong muriatic acid to saturation, it gives a brown solution, which, by gradual evaporation, (rapidly by oil of vitriol) passes into the blue *terchloride*, is obtained by passing chlorine through an ignited mixture of suboxide and charcoal. It condenses to a light yellow liquid, which boils above 212° , fumes in the air, forming, by the moisture, muriatic and vanadic acids, and runs to a red liquid; it absorbs ammonia, and becomes white, and this body, distilled in a current of ammonia, yields vanadium. The blue solutions of the oxide in bromo- and iodo-hydric acids, change readily in the air. The blue solution in fluohydric acid, forming the bifluoride, leaves, by evaporation, a brown residue, soluble in water; and by spontaneous evaporation a green syrup, in which green crystals are formed. The latter are soluble in alcohol, and the tincture becomes blue by sulphohydrogen. It forms soluble double salts with alkaline fluorides. Fluohydric acid dissolves vanadic acid, but the perfluoride is easily decomposed. Silicofluoride, an orange-colored, amorphous mass, partly dissolving in water, with a yellow color, and partly remaining as a dark green mass.

6. *Oxysalts.* Sulphate, $\text{VO}_2, 2 \text{SO}_3$, is obtained by dissolving vanadic acid or oxide in oil of vitriol, diluted with an equal weight of water, passing sulphohydrogen through the dilute solution to reduce vanadic acid, and evaporating, when a dirty blue crust of the salt is deposited. It is washed with absolute alcohol, and becomes a cerulean powder, which is deliquescent, and then soluble in water; the crystals from the deliquescent mass, and the blue powder, contain 4 eq. HO . It forms an uncrystallizable double salt with sulphate of potassa. The nitrate is obtained only as a blue solution. The neutral phosphate, VO_2, PO_5 , forms a blue, uncrystallizable syrup, which if mixed with absolute alcohol, gives a grayish blue precipitate, probably a basic salt. The baborate, $\text{VO}_2, 4 \text{BO}_3$, is a grayish white precipitate.

7. *Vanadates.* Neutral vanadate of potassa
4 K 937

yields, by evaporation, a white, earthy mass. The bivanadate is obtained by adding strong acetic acid to an almost boiling solution of the neutral salt, until the precipitate is redissolved, precipitating by alcohol, dissolving the precipitate in water, and crystallizing. It forms orange-yellow crystals, of the composition KO , $2 \text{VO}_3 + 3 \text{HO}$, which lose their water by heat, become brick-red, and are then fusible. The two salts of soda and of lithia are similar. The neutral salt of ammonia is obtained by digesting vanadic acid with ammonia, to form bivanadate, supersaturating with ammonia, warming the yellow solution until it is discolored, and letting it crystallize, or precipitating it by alcohol. Another method is, to put a mass of salammoniac into a solution of neutral vanadate of potassa or soda. It is white, crystalline, and has the form. NH_4O , VO_3 . If the yellow solution be not heated, and then be suffered to evaporate, a yellow crystalline modification is obtained. The bisalt is obtained like that of potassa, and forms large transparent crystals. The acid forms basic, neutral, and bi-salts, with baryta, strontia, and lime, those of baryta being least, and those of lime most soluble. The neutral salt of magnesia is very soluble, the acid salt slightly soluble. The salts of the metals proper, are yellow, reddish, or brown, generally insoluble, or difficultly soluble in water.

8. Salts, with vanadic acid as base. The sulphate of vanadic acid is obtained by dissolving vanadic acid in oil of vitriol, diluted with half its weight of water, and evaporating off the excess of acid at the lowest possible heat; it forms reddish brown, crystalline scales, deliquescent and very soluble, and giving a double salt with sulphate of potassa. The neutral sulphate of the oxide, dissolved in nitric acid, and evaporated to dryness, a red basic salt, VO_3 , 2SO_3 . The nitrate of vanadic acid leaves a red residue by evaporation. The phosphate is obtained by dissolving phosphate of the oxide in nitric acid, and evaporating off the excess of nitric acid; it is yellow, crystalline, and has the form. 2VO_3 , 3PO_5 . This salt forms a double salt with phosphate of soda, when phosphate and vanadate of soda are mixed in solution, treated with nitric acid and evaporated. The most remarkable compound is that with silicic and phosphoric acids, made by adding nitric acid to mixed solutions of phosphate, vanadate, and silicate of soda, and evaporating. It forms yellow, shining scales, with the form, 2SiO_3 , $\text{PO}_5 + 2 \text{VO}_3$, $\text{PO}_5 + 6 \text{HO}$. It is quite soluble in water, and yields the same scales by evaporation.

VAPOR. See tables in the Appendix.

VAREC. See SODA.

VARGASITE. A pale-green, columnar mineral, not further described.

VARIEGATED COPPER. *Min.* Buntkupfererz. Cryst. Regular; the cube and 8-hedron, sometimes twinned on a plane of the latter; also granular. $H. = 3$. $G. = 5.003$. Copper-red to pinchbeck-red, tarnishing readily in the air with iridescence and prevalence of blue, lustre metallic, brittle with uneven fracture, and grayish black, shining streak. It fuses on coal to a brittle, magnetic globule, gives off sulphurous gas, and after roasting gives with

soda particles of metallic iron and copper separated, soluble in muriatic acid, leaving sulphur. Form. $3 \text{Cu}_2\text{S}$, Fe_2S_3 , containing $55\frac{1}{2}$ pr. ct. metallic copper, and 16 pr. ct. iron; but as it is apt to have copper pyrites and vitreous copper mingled with it, the percentage of copper varies. It is not a rare ore of copper, either alone or associated with copper pyrites. Flemington, New Jersey, and Bristol, Connecticut, are among American localities. The crystals have been found in Cornwall.

VARIOLA AMARA. A lichen, growing in grayish crusts upon the bark of beech trees, in mountainous regions. It is used as a tonic and febrifuge in certain cases, (*Journ. de Pharm.* 1844).

Müller found in 100 pts. of the lichen—

Pikrolichenin	2.395
Brownish yellow resin, (by ether).....	0.677
Dark green, bitter resin.....	1.979
Chlorophyll.....	4.114
Mucous sugar.....	1.960
Bitter extractive, (by water).....	3.645
Oxalic acid.....	3.208
Lime	2.521
Silica	1.770
Iron	traces
Lignin and undetermined matters.....	77.731

Pikrolichenin is the bitter principle first discovered by Alms. It forms crystals, which are only slightly soluble in cold alcohol of .912.

VARIOLITE. See FELDSPAR.

VARISCITE. *Min.* Reniform. $H. = 5$. $G. = 2.345—2.379$. Apple-green; feeble, greasy lustre; translucent; white, shining streak. It yields alkaline water in a tube; infusible; gives a yellowish green glass with borax. Chiefly composed of phosphoric acid and alumina. From Massbach, in Voigtland.

VARNISH. *Fr.* Vernis. *Ger.* Firniß. The term varnish applies to those liquids which impart a brilliant polish to solid surfaces. They consist mostly of finely divided resinous matter, dissolved or suspended in a suitable menstruum. These liquids are applied in coats by means of a brush, and when thus exposed leave by evaporation a hard, brilliant, and transparent adherent covering, retaining all the properties of the original resin with additional lustre. A good varnish should afford a durable polish unalterable by either air or moisture. The usual resins are mastic, amber, sandarac, shellac, elemi, colophony, animè, and copal; the menstrua are spirits, essences, and oils. When alcohol, or like liquids, are the vehicle, the varnishes are termed "*spirit varnishes*." These lose all their solvent by evaporation, and are the most brittle. Turpentine alone gives a more plastic and solid varnish, for being itself partially resinified by evaporation improves the properties of the resins employed. "*Oil*" or "*fat*" varnishes dry slower, but are more permanent. Each, however, has its appropriate application.

In the manufacture of varnishes great care and cleanliness should be observed. The resins should be washed in hot water to remove dusty and dirty particles, then dried and assorted in shades, reserving the lightest-colored pieces for the finest varnishes.

VARNISH.

SPIRIT VARNISHES.

Copal, in fine powder.....	5 pts.
Sulphuric ether, pure.....	2 “

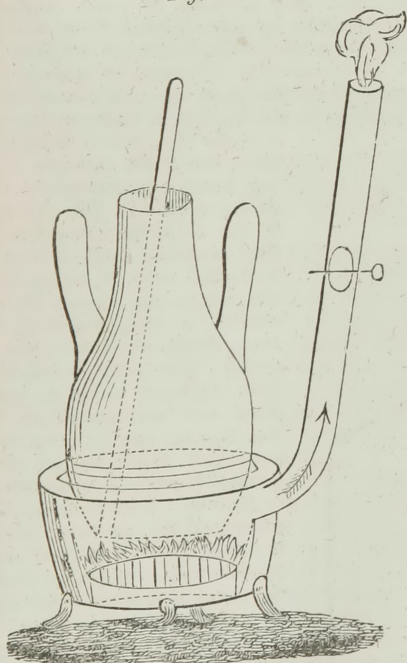
Agitate the two together in a stoppered flask for an hour, allow a day's repose, and then add two additional pts. of ether, and agitate as before. This yields a very transparent, brilliant polish. Place in a flask—

Alcohol.....	500 pts.
Ether	60 “

In this hot mixture a bag is to be suspended, containing 120 pts. of copal previously oxidized by long exposure in powder, and the whole heated until complete solution. This varnish is very white and drying. According to Berzelius, if powdered copal is digested with ether, the syrupy mixture heated to ebullition, and then heated with small quantities of warm alcohol of .82 spec. grav., a limpid solution is formed, by agitation, which will bear dilution with alcohol to a large extent.

The advantages of this kind of varnish are solidity, and brilliant, and colorless transparency. It is, however, only available for interior work, and for fancy and fine articles. A combination of soft and hard resins gives a much better varnish than either alone. The stronger the alcohol the better the quality of the product, and as direct application of fire is apt to generate color, the mixture of the materials should be made by simple digestion in a water-bath, as shown by Fig. 92.

Fig. 92.



Varnish for Paper Articles.

Alcohol, 36°—40° B.....	32 pts.
Washed mastic.....	6 “
Sandarac.....	3 “
Venice turpentine.....	3 “
Bruised glass.....	4 “

VARNISH.

Mix together and place the glass, sandarac, and mastic, previously powdered, in a tinned-copper digester, (Fig. 92), of capacity sufficient for double the quantity of varnish to be made; add the alcohol, heat the whole by means of a water-bath, and stir constantly with a smooth wooden spatula. After several hours, when solution is complete, add the turpentine, stir thoroughly, warm for an hour, remove from the fire, and the next day strain through cloth. This mode of manipulating is of general application to all of the spirit and essence varnishes.

Varnish for Light Articles of Furniture.

Galipot (selected).....	3 pts.
Animè } each.....	1 “
Elemi }	
Bruised glass.....	2 “
Alcohol 36° B.....	16 “

Copal Varnish.

Oxidized copal.....	1 pts.
Alcohol, 40° B.....	3 “

Digest for a week or more, taking care to agitate several times daily.

Varnish for White Woods.

Bleached shellac (recent).....	3 lbs.
Alcohol of 40° B.....	2½ galls.

Melt the shellac in 1 gallon of the spirits, and then add an half gallon more. After straining, mix in the residue. If color is required, a portion of the alcohol may be previously tinted by red sanders, but in this case it is more economical to use unbleached shellac of a light color.

Brilliant and Colorless Spirit Varnish.

Bleached shellac.....	8 pts.
Sandarac (washed).....	4 “
Bruised glass.....	4 “
Alcohol, 40° B.....	60 “

Varnish for Musical Instruments.

Sandarac.....	4 pts.
Seed lac.....	2 “
Mastic, in tears.....	2 “
Elemi.....	1 “
Bruised glass.....	4 “
Venice turpentine.....	2 “
Alcohol.....	32 “

Either of these varnishes may be colored by the addition of suitable pigment. For example, dragon's blood and sanders yield red, saffron and gamboge, yellow.

ESSENCE VARNISHES.

These, as well as their mode of manufacture, are very analogous to the preceding, and though less siccativ possess the advantages of affording a durable polish less liable to crack or damage by rubbing.

Table Varnish.

Rub up finely-powdered dammar resin, (selected and washed), with double its weight of recently distilled, clear spirits of turpentine, and add 200 grains of camphor to every lb. of resin employed. The whole is then to be digested in a close vessel for 24 hours, and frequently shaken in the interval. The supernatant, clear portion, is then decanted for use. Exposure while being heated over a water-bath

will remove any color, and impart perfect limpidity.

Common Table Varnish.

Dissolve 3 lbs. of Venice turpentine in 8 lbs. of hot spirits of turpentine, and then transfer the clear liquor to a cool, open vessel.

Copal Varnish for Inside Work.

Copal, in powder.....	6 pts.
Fresh spirits of turpentine.....	10 "

This varnish is rendered less brittle by a slight addition of camphor.

Transfer Varnish, (mordant.)

Mastic	4 pts.
Sandarac.....	4 "
Gamboge.....	2 "
Turpentine.....	1 "
Spirits of turpentine.....	24 "

Copal Varnish.

Copal	30 pts.
Oil of lavender.....	180 "
Camphor.....	4 "

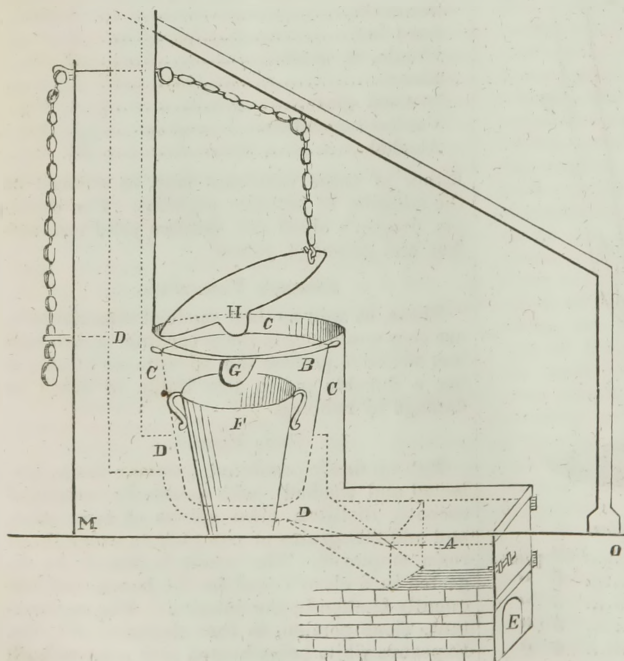
Spirits of turpentine { *q. s.* to give the proper consistence.

Add the copal portionwise to the heated oil, holding the camphor in solution, and promote the mixture by constant stirring; then gradually add the spirits to the hot varnish. The product is light colored, and gives a solid, transparent, flexible coating.

OIL VARNISHES.

These varnishes, composed of a very intimate mixture of resin, oil, and spirits of turpentine, differ from the preceding in being less drying, but give a polish of greater lustre and solidity, and more resistant to the effects of heat, light, and sudden changes of temperature.

Fig. 93.



Their application, therefore, is of extended usefulness, as they are specially adapted for house, panel, carriage, and other work, which require frequent washing.

The oils almost exclusively used for this purpose are those of linseed and walnuts. The gums are the different kind of copal and amber.

As the oil, especially when new, always contains mucilage and more or less foreign matter, and as these ingredients prevent the ready absorption of oxygen by the oil—a very necessary condition in order that it may become siccative—it is necessary to give a preliminary treatment to render it proper for varnish. The best method, it is said, is to rub the raw oil with dry sulphate of lead until it has a milky appearance. The mixture is then to be exposed to the light for several days, and frequently stirred during the interval. During this repose, the sulphate of lead precipitates, carrying with it most of the mucus and impurities, while the residue forms a compact membrane from which the supernatant clear oil can be decanted. This oil dries quickly, and whitens entirely in time. The process, also, is economical, particularly as the lead sediment may be repeatedly used after separation of the mucous deposit.

The above method, however good, is not that usually adopted for improving the drying power of oil. The common plan is to boil it with dryers, such as litharge, red lead, white vitriol, &c. The "oil varnish" thus obtained is, however, inferior in properties to that prepared with the sulphate of lead. This latter, after purification, may perhaps be better adapted for its purpose by subsequent boiling, and so we give the mode:—The boiler for the purpose must be of capacity sufficient for double the quantity of its charge of oil. Its construction and position in the furnace is shown at fig. 93.

A is the iron-bound brick furnace, and B the cast-iron boiling kettle, enveloped in the mason work C. The chimney is seen at D, the ash-pot at E. The receiving kettle is shown at F, the cover, H, fitting over the whole top, spout G included, is suspended by an iron chain working upon a pulley. The boiler, previously well cleansed, is to be half-filled with old linseed oil, as that having age is more drying, and then heated very gradually until it commences to simmer. This heat may be continued for an hour, so as to expel all moisture, but care must be taken to skim off all the scum as it rises to the surface. (It is at this stage, in the old method, that the driers are added. The proportions are 14 lbs. litharge, 12 lbs. red lead, and 8 lbs. recently burned amber, to be well powdered and gradually sprinkled in, and prevented adhering to the bottom by frequent stirring. The heat is continued

gently for 2 hours longer, and after 24 hours cooling and repose, the clear oil is decanted and strained.) After this the heat may be cautiously increased until the oil bubbles, and subsequently becomes calm. At this stage it emits gaseous vapor, which flashes when put in direct contact with a lighted taper. As soon as the vapor can be inflamed in this way, the fire is to be discontinued, the scum removed, and the oil allowed to cool. If the oil has been too highly heated, the vapor, instead of flashing, will burn continuously, and cause loss or damage, unless the flame is immediately extinguished by closing the kettle with the lid. The oil, after straining, is thus rendered suitable for varnish.

The next step is the selection of the resin. Copal is that most generally employed. Of this there are several species and grades. That from Calcutta is the best, but whatever the kind, it should be washed to remove dirt, and culled in regard to shade and fusibility. The whiter pieces are to be reserved for the fine quality of varnish. A very good mode of testing the fusibility, is to soak the resin in an alkaline ley (1 lb. pearlash to 70 lbs. water) for 48 hours, and then removing every trace of alkali by repeated washing in fresh waters. The more fusible pieces are then softened, and can be accordingly separated from the harder and more refractory. Subsequent exposure to sun effects the necessary drying.

The oil and copal being prepared, it is necessary, before proceeding to the manufacture of varnish, to bear in mind the following precautions:—

1. That oil varnish is not a solution, but an intimate mixture of resin in boiled oil and spirits of terpentine.
2. That the resin must be completely fused previous to the addition of the boiled or prepared oil.
3. That the oil must be heated to 250°—300°.
4. That the spirits must be added gradually and in thin stream, while the mixture of oil and resin is still hot.
5. That the varnish should be made in dry weather, otherwise moisture is absorbed, and its transparency and drying quality impaired.

The heating vessel must be of copper, with a solid bottom fastened by rivets, and not soldered. A flange on the exterior serves as its support upon the ledge of the furnace. The whole arrangement is seen at fig. 93, before given. An iron stirrer and a brass sieve comprise the remainder of the furniture.

As before said, the copal does not dissolve, but mixes with the hot oil. To promote this action, the copal is first fused alone in the kettle, over a moderate charcoal fire kept constantly supplied with fuel, without disturbing the kettle, until the completion of the mixture with oil. If it is melted in the boiling oil, the resulting varnish is more colored and less drying. There is, however, great care required in fusing the copal by itself; for if the heat is not carefully managed, or if it is too much prolonged, the resin becomes pitchy, and gives an inferior varnish. Constant stirring is requisite, to prevent adhesion to the sides and bottom of the vessel, and consequent scorching. As a partial preventive, all the pieces of copal should

be of uniform fusibility; for example, amber requires a higher heat for fusion than hard copal; this latter higher than that for the demi-hard variety; and this again is of more difficult fusion than tender copal. The different varieties should therefore never be fused together, for that which melts first may be scorched by the high heat required to melt those that are more refractory. If it is desired to mix them in order to regulate the quality of the varnish, it must be in a state of fusion.

When the melted resin is perfectly fluent, the hot oil is then to be ladled in gradually, during constant stirring, with the iron spatula. To determine the perfection of the mixture, a drop must now and then be taken out, and cooled upon a glass plate. If on cooling it is limpid and takes a wax-like consistence, penetrable with the nail without cracking, the proper proportion of oil has been added; on the contrary, if it is hard and brittle, more oil is required. The precise amount of liquid can only be determined by experiment, for resins vary in their saturating power. As a general rule, the hard and demi-hard copal will bear one-half their weight of oil, and a little more than their weight of spirits for a good varnish, drying in 24 hours. The best way, however, is to test every new lot of resin on a small scale.

The spirits of terpentine is added while the mixture of oil and resin is still hot. It should be previously warmed, and allowed to flow in a thin stream and during constant stirring. If viscosity should ensue, the addition of terpentine must be immediately stopped, and the mixture replaced over the fire and heated gradually up to 600°. Limpidity is thus restored, and upon removal from the fire a *q. s.* of spirits of terpentine may then be added, to impart the proper consistence. The product is, however, inferior to that which would have resulted by proper observation of the rules before recorded.

So, likewise, when the oil, by reason of any content of water or other impurity, makes an opaque mixture with the melted resin; or when added too cold it produces clots, the remedy is to boil, and add spirits of terpentine, as is usual, and then strain. This varnish, however, is inferior and less homogeneous than would have resulted from skilful management.

The proportions of ingredients of a good varnish are—

Copal.....	3 lbs.
Prepared oil.....	1½ “
Ess. terpentine	4—5 “

Amber Varnish.

Amber.....	2 lbs.
Prepared oil.....	3 “
Ess. terpentine	<i>q. s.</i>

Black Japan Varnish.

Hard copal.....	3 lbs.
Boiled asphaltum.....	1 “
Oil prepared with dryers.....	2—3 “
Ess. terpentine.....	6.75 “

Amber may be substituted for copal, but the varnish is less brilliant.

Japan (Copal) Varnish.

Pale, African copal, 7 lbs.; fuse, add an ½
4 κ 2 941

gallon of prepared linseed oil, boil for five minutes, and remove from the fire. Then mix in intimately 3 galls. hot oil of turpentine, and strain into a covered cistern. This varnish, used by japanners, dries in fifteen minutes, and may be polished as soon as it has hardened.

VARVICITE. *Min.* Crystalline plates and fibres. $H.=2.5-3$. $G.=4.283-4.623$. Steel-gray, iron-black; submetallic; opaque; black streak. Form. Mn_2O_3 , $HO + 2 MnO_2$. Probably a mixture of the two oxides.

VAUQUELINITE. *Min.* Cryst. Oblique rhombic; also imitative and amorphous. $H.=2.5-3$. $G.=5.5-5.78$. Dark-green, nearly black; adamantine; subtranslucent, opaque; rather brittle, with uneven fracture and siskin-green or brownish streak. It swells up on coal, and fuses with much effervescence to a dark gray, metallic, shining globule. The fluxes give a green glass in the outer flame, and mic. salt shows copper in the inner flame, especially by adding tin; soda gives a green glass in the oxidizing flame, which becomes yellow on cooling. Partly soluble in nitric acid, with a yellow residue. Form. $3 CuO$, $2 CrO_3 + 2 (3 PbO, 2 CrO_3)$. From Beresof, Siberia; near Sing-Sing, N. York, &c.

VEGETABLE IVORY. The seeds of the *Phytelapha macrocarpa* and *microcarpa*, imported into Europe from Peru.

VELVET COPPER. *Min.* Kupfersamterz. In spherical or mamillary masses of short, delicate fibres, of the finest cobalt-blue, with a silky lustre. Contains silicic and sulphuric acids, with oxides of copper and zinc. From Moldwa.

VERATRIN. *Pharm. Chem.* A poisonous alkaloid, existing in the root of HELLEBORE, and in the seeds of SABADILLA.

Prep. Dissolve the alcoholic extract of sabadilla in dilute sulphuric acid, heat with animal charcoal, and precipitate by an alkali. To separate the veratrin from sabadillin and other impurities, the precipitate is redissolved in dilute oil of vitriol, and nitric acid is then added until black sediment ceases to be formed. Filter, and precipitate the filtrate by dilute potassa: wash dry, and dissolve the precipitate in absolute alcohol. Evaporate, treat with boiling water, to remove sabadillin, &c. The residue yields the veratrin to ether.

Prop. Formula $C_{34}H_{28}NO_6$. Is an uncrystallizable, white powder, soluble in alcohol, less so in ether, and but very slightly in water. Melts at 239° . Its muriate and sulphate are crystallizable.

VERATRIC ACID. See SABADILLA.

VERATRUM. See HELLEBORE and SABADILLA.

VERD ANTIQUE. *Geol.* A green porphyry, composed of a feldspathic paste imbedding detached crystals of the same, and usually of a lighter color.

VERDIC ACID. } Extracted from the roots

VERDOUS ACID. } of the *Scabiosa succisa*; but existing also in a variety of plants of the families Dipsacæ, Compositæ, and Eupatoriæ. Their properties are undetermined.

VERDIGRIS. Acetate of COPPER.

VERDITER. *Tech. Chem.* Sym. Bremen green. A bluish green pigment, consisting of

a mixture of the hydrate and carbonate of copper. The process for its manufacture is as follows:

a. 225 lbs. of sea salt, and 222 lbs. of blue vitriol, both free from iron, are mixed in the dry state, then reduced between mill-stones with water to a thick homogeneous paste.

b. 225 lbs. of plates of old copper are cut by scissors into bits of an inch square, then thrown and agitated in a wooden tub containing two lbs. of sulphuric acid, diluted with a sufficient quantity of water, for the purpose of separating the impurities; they are afterwards washed with pure water in casks made to revolve upon their axes.

c. The bits of copper being placed in oxidation-chests, along with the magma of common salt and blue vitriol previously prepared in strata of half an inch thick, they are left for some time to their mutual reaction. The above chests are made of oaken planks joined without iron nails, and set aside in a cellar, or other place of moderate temperature.

The saline mixture, which is partially converted into sulphate of soda and chloride of copper, absorbs oxygen from the air, whereby the metallic copper passes into a hydrated oxide, with a rapidity proportioned to the extent of the surfaces exposed to the atmosphere. In order to increase this exposure, during the three months that the process requires, the whole mass must be turned over once every week, with a copper shovel, transferring it into an empty chest alongside, and then back into the former one.

At the end of three months, the corroded copper scales must be picked out, and the saline particles separated from the slimy oxide with the help of as little water as possible.

d. This oxidized *schlam*, or mud, is filtered, then thrown, by means of a bucket containing 30 pounds, into a tub, where it is carefully divided or comminuted.

e. For every six pailfuls of *schlam* thus thrown into the large tub, 12 pounds of muriatic acid, at 15° Baumé, are to be added; the mixture is to be stirred, and then left at rest for 24 or 36 hours.

f. Into another tub, called the blue back, there is to be introduced, in like manner, for every six pailfuls of the acidified *schlam*, 15 similar pailfuls of a solution of colorless cleat caustic alkali, at 19° Baumé.

g. When the back (e) has remained long enough at rest, there is to be poured into it a pail of pure water for every pail of *schlam*.

h. When all is thus prepared, the set of workmen who are to empty the back (e), and those who are to stir (f), must be placed alongside of each. The first set transfer the *schlam* rapidly into the latter back; where the second set mix and agitate it all the time requisite to convert the mass into a consistent state, and then leave it at rest from 36 to 48 hours.

The whole mass is to be now washed; with which view it is to be stirred about with the affusion of water, allowed to settle, and the supernatant liquor is drawn off. This process is to be repeated till no more traces of potash remain among the blue. The deposit must be then thrown upon a filter, where it is to be kept moist, and exposed freely to the air. Th

pigment is now squeezed in the filter-bags, cut into bits, and dried in the atmosphere, or at a temperature not exceeding 78° Fahr. It is only after the most complete disiccation that the color acquires its greatest lustre.

An inferior article is made by precipitating nitrate of copper with chalk, stirring the mixture until the liquor loses color, decanting, washing, filtering, and drying in the sun. A trituration of the precipitate in its pasty state, produces uniformity and beauty of color.

VERMICULITE. *Min.* Probably PYRO-PHYLLITE.

VERMILLION. See MERCURY.

VESUVIAN. See IDOCRASE.

VESUVIAN SALT. See APHTHALITE.

VIGNITE. *Min.* A very blue magnetic iron, probably a mixture of magnetic iron, carbonate, and phosphate of iron.

VILLARSITE. *Min. Cryst.* Right Rhombic, 8-hedral. $H. = 3 - 3.5$. $G. = 2.975$. Yellowish green; sub-transparent; infusible, giving a green enamel with borax; decomposed by strong acids. From Traversella, Piedmont.

VINEGAR. See ACETIC ACID.

VINOUS FERMENTATION. See FERMENTATION, ALCOHOL, and ETHYL.

VIOLET. *Min.* Amorphous. $G. = 3.233$. Violet blue, waxy, opaque; fusible by a strong heat. It is a silicate of alumina, magnesia, lime, protoxide of iron, and soda. From St. Marcel, Piedmont.

VIRIDIC ACID. A product of the oxidation of Pfaff's Caffeo-tannic acid. Form. $C_{14}H_6O_7$, (Rochleder, *Liebig's Annalen*, lxiii.) The aqueous solution gives a bluish green precipitate, with barytic water. It appears to be identical with Runge's green acid from COFFEE.

VITELLIN. See EGG; and Nod's paper in *Chem. Gaz.* v. 410.

VITREOUS COPPER. *Min.* Copper glance, Sulphuret of copper, Kupferglanz. *Cryst.* Right rhombic; prismatic and 8-hedral; often compounded like arragonite; also granular. $H. = 2.5 - 3$. $G. = 5.5 - 5.8$. Streak and color grayish black, sometimes tarnished; metallic; opaque; fracture conchoidal; sectile, with shining streak. Colors the blowpipe flame blue; evolves sulphurous acid by roasting; fuses readily in the outer flame; yields copper with soda; soluble in nitric acid, leaving sulphur. Form. Cu_2S . It is frequent in copper mines. Beautiful and large crystals occurs at Bristol, Connecticut.

VITREOUS SILVER. *Min.* Sulphuret of silver; Silberglanz; Glaserz. *Cryst.* Regular. Pl. VIII, figs. 1, 2, 3, 4, 6, 8, 9, &c. Also, filiform and amorphous. $H. = 2 - 2.5$. $G. = 7.196 - 7.365$. Streak and color grayish black; shining; metallic; opaque; negatively electric by friction. It fuses on coal, swelling up; evolves sulphurous acid, leaving a globule of silver; soluble in nitric acid, leaving sulphur. Form. Ag_2S . It is one of the most important ores of silver occurring in the Erzgebirg, Hungary, Mexico, &c. I found a small quantity in the ore from Davidson county, North Carolina.

VITRIOL. The former name for metallic sulphates, whence vitriolic acid, the name for sulphuric acid employed in the last century. The terms green, blue, and white vitriol, are

still retained in commerce for the sulphates of iron, copper, and zinc.

VITRIOL OCHRE. See COQUIMBITE.

VIVIANITE. *Min.* Phosphate of iron, Blue iron earth, Mullicite, Eisenblau, Glaukosiderit, Eisenphyllit, Siderischer Diatomphyllit. *Cryst.* Oblique rhombic, prismatic, with terminal planes; with a perfect cleavage, parallel with a lateral end-plane; also imitative and earthy. $H. = 1.5 - 2$. $G. = 2.661$. Colorless and transparent previous to exposure to air; changing by exposure to sea-green and sometimes blue, and usually becoming translucent unless in well-defined crystals; lustre vitreous, pearly on cleavage-plane; brittle, with an almost colorless streak when fresh, but blue after exposure. The earthy variety is a white, opaque powder when fresh, becoming blue by exposure.

In a tube it gives water, puffs, and becomes gray and red; on coal it burns red, fuses to a gray, shining globule, and shows the presence of iron with the fluxes; soluble in nitric or muriatic acid, and perfectly decomposed by fusion with carbonate of soda. The formula of the fresh mineral is doubtless $3 FeO, PO_5 + 8 HO$; but by oxidation a portion of the iron oxidizes still higher, and a portion of water is lost, so that the blue mineral contains a large proportion of the former with a small quantity of $3 Fe_2O_3, 2 PO_5 + 8 HO$.

Local. It has many localities, is often associated with shells in the secondary and tertiary softer rocks, and with more modern bog-ore. It is especially abundant in many parts of the green-sand formation in New Jersey, Delaware, and Maryland, and I found well-defined crystals in Delaware. (See *Sil. Journ.* 1850.)

VOLATILITY. The property of subliming, unaltered, at low temperatures.

VOLBORTHITE. *Min.* Vanadinkupfererz. In small aggregated globules, harder than calc. spar. $G. = 3.55$. Olive-green, with yellowish green streak; vitreous; thin splinters transparent, translucent. Yields water in a tube, and becomes black; fuses on coal in the outer flame to a black slag, and by a continued heat leaves a globule of copper; shows copper with all the fluxes; soluble in nitric acid, from which water throws down after some time a brick-red precipitate of vanadic acid. Probably from between Miask and Katherinenburg.

VOLCANIC ASHES. *Geol.* Finely-pulverized mineral matter ejected from volcanoes, containing minerals soluble in muriatic acid, and others (feldspathic?) not soluble. See TRASS.

VOLCANIC GLASS. See OBSIDIAN.

VOLCANITE. See AUGITE.

VOLCKNERITE. *Min.* A white pearly mineral. $G. = 2.04$. Yields water, exfoliates, and is infusible; dissolves in the fluxes with effervescence. Form. $6 MgO, Al_2O_3 + 15 HO$. From the Ural.

VOLKHONSKOITE. *Min.* Amorphous, green, dull, shining, resinous touch, polished by the nail; very brittle; adheres to the tongue; contains chiefly silica, oxides of chrome, and iron, and water. From Siberia. See MILOSKIN.

VOLTAITE. *Min.* *Cryst.* Regular. Brown or black; soluble in water with decomposition. Form. $3 (RO, SO_3) + 2 (R_2O_3, 3 SO_3) + 12 HO$. The $RO =$ chiefly FeO with a little KO, NaO ,

and the R_2O_3 = chiefly Fe_2O_3 with a little Al_2O_3 . From the Solfaterra, near Naples, and since made artificially by Abich.

VOLTZITE. *Min.* In spherical globules. $H. = 4.5$. $G. = 3.66$. Dirty rose-red, yellowish, vitreous, greasy, opaque or subtranslucent. Behaves like blende. Form. $ZnO + 4 ZnS$. From Rosiers, Dpt. Puy de Dome, and the cinders of many iron furnaces.

VORAUITE. See LAZULITE.

VULPINITE. See ANHYDRITE.

W.

WACKE. *Geol.* An earthy basalt.

WAD. *Min.* Amorphous, and imitative, without crystalline structure. It is a soft, brown or black, friable, earthy oxide of manganese, but the state of oxidation is uncertain. As Rammelsberg suggests, it has probably arisen from psilomelan by a pseudomorphic change.

WAGNERITE. *Min.* Cryst. Oblique rhombic. $H. = 5-5.5$. $G. = 2.985-3.11$. Yellow, sometimes grayish, vitreous, translucent, fracture splintery. It fuses with difficulty in thin splinters to a dark greenish, gray glass; moistened with oil of vitriol, it colors the flame bluish green; dissolves in the fluxes, and fuses with soda; soluble in nitric and sulphuric acids with evolution of fluohydric acid. Form. $MgF + 3 MgO, PO_5$. From Höllgraben, near Werfen, in the Pongau of Salzburg.

WARWICKITE. *Min.* Cryst. Oblique rhombic. $H. = 5.5-6$. $G. = 3-3.29$. Resembles hypersthene, for which it was formerly taken. It consists chiefly of titanium and fluorine with 7 pr. ct. iron, according to Shepard's analysis. Berzelius remarks, that such a result is very improbable, and that it might be rutile with titanite iron, and some fluoride of iron. But both the crystalline form and spec. grav. are against such a view. From near Edenville, New York.

WASHINGTONITE. See TITANIC IRON.

WATER. *Chem. Tech.* Syn. Oxyhydric acid, Protoxide of Hydrogen. *Ger.* Wasser. *Fr.* Eau. One of the so-called elements of the older philosophers. A transparent, inodorous, scarcely compressible liquid, diffused throughout nature, as vapor in the air, as water of CRYSTALLIZATION in crystals, as a constituent of innumerable inorganic and organic bodies, and as the material of oceans, seas, lakes, rivers, springs, and fountains. Its composition was first announced in 1783, by Priestley, Cavendish, and Lavoisier. Water plays an important, indeed an indispensable part in domestic economy, in the practice and furtherance of the useful arts, and in analytic chemistry. As the source of steam, it may be considered as a prime element in human progress.

Prep. By the union of one volume of oxygen with two volumes of hydrogen, by combustion, compression, electricity, or contact of platinum. The intense heat evolved during this reaction constitutes the principle of Dr. Hare's hydroxygen or compound BLOWPIPE. Water may also be produced by igniting many metallic oxides in contact with dry hydrogen gas, and during many chemical changes.

Prop. Symbol HO. Eq. = 9. It is the unit by which the density of solids and liquids are compared, and therefore its spec. grav. is 1. The percentage composition of water is, hydrogen 11.11 and oxygen 88.89.

As found in nature, it is more or less impregnated with gaseous and saline matters, which impart, in many instances, medicinal properties, and thus give to certain waters their value as therapeutic agents. The soluble matters vary in nature and proportion with the source of the water and the constituents of the soil which it traverses. Those waters rich in chloride of sodium are called SALINES. All of the solid constituents may be retained by DISTILLATION, the water passing over pure and suitable for purposes of analytic chemistry and pharmaceutical dispensation. The first portions of the distillate contain the volatile and gaseous matters and must be rejected. The residue in the still contains all the fixed portion, provided the heat has not been raised above 212° . To obtain water chemically pure, it may be distilled from a copper-still, well tinned on the inner surface, and with a helm and cooler of solid tin. Those made in Germany are of the best forms and material. Distilled water, as well as that which is boiled, is insipid, owing to the expulsion of air and carbonic acid which impart pungency of taste.

The suspended matters contained in waters may be separated by standing or by FILTRATION. The incrustations which form on the sides of steam boilers, tea kettles, &c., are the saline and earthy constituents which have dropped from the water during its concentration by evaporation. They generally consist of sulphate of lime, &c. So also stalactites and stalagmites are formed in caves by the spontaneous evaporation of water surcharged with lime salts. Putrid waters owe their offensive taste and smell to the presence of suspended organic matter. As long as they retain the least portion of these fermentable particles, putrescence will inevitably ensue, and hence such waters are unsuitable for brewers, ships, or domestic use. Careful and repeated filtration through charcoal and sand is the most effectual remedy.

Water appears colorless in small quantities, but in large volumes is blue by reflected, and green by transmitted light. A very characteristic property is its solvent power, and hence its use as a standard for the comparison of the solubility of bodies. (See SOLUTION and ABSORPTION.) With few exceptions this power is increased by heat as to solids, but with regard to gases the lower the temperature of the water the greater the amount of gas taken up. In this process of solution bodies are rarely affected in their chemical condition by the water. In certain cases, for example nitrate of bismuth, an insoluble salt is formed by diluting its solution with water. Those gaseous or volatile matters which are not in definite combination with the water may be expelled by heat.

The compounds which it forms with organic and inorganic bodies are termed *hydrates*. (See HYDROGEN.)

Those substances which are absorbent of moisture are called deliquescent or hygroscopic, and according to the extent of this property

depends their use for DESICCATION in ANALYSIS.

Water is limpid down to 32° , when it congeals. If the water is kept in strict repose and cooled very gradually, its fluidity may be retained to a much lower temperature. This freezing process is a true crystallization, resulting in ice, snow, hail, or frost, according to temperature and volume of water. In ice, the crystals are confused and aggregated; in snow they are stellated groups of six-sided prisms; in frost regular hexahedral laminæ.

The liquefying point of ice being constant is taken as the zero in the graduation of THERMOMETERS. Unlike most other bodies, water expands in congealing, and with such force as to shatter the stoutest containing vessel. This expansion is partly due to the accidental incorporation of air bubbles during freezing, and hence the ice is less dense than water. Ice in liquefying renders latent heat sufficient to warm an equal quantity of water at 39° to 167° . It is this absorption of heat in melting that gives to ice all its usefulness for freezing cream and for other cooling purposes. See HEAT.

Contraction ensues from 32° to 39.2° upon application of heat; and conversely, by cold, dilates from 39.2° to many degrees below its freezing point. This property of irregular EXPANSION in certain ranges of temperature has an important bearing in the economy of nature, as shown at page 619. The maximum density of water being 39.2 , that is the degree at which it is sometimes taken for comparing the densities of solids and liquids.

Water is 815 times heavier than atmospheric air, and one cubic inch at 62° and 30 bar. weighs 252.458 grains. At 212° it boils, if pure, for the presence of saline matters decreases its tension and consequently raises its boiling point. The amount of heat required to convert water into elastic vapor is five and an half times greater than is necessary to raise it from 32° to 212° . The pressure of the atmosphere being removed, the boiling temperature is reduced, and upon this law is founded the economical mode of EVAPORATION in vacuo.

Water is indecomposable by heat, but is reduced by electricity and by many of the simple bodies; thus potassium, sodium, &c., abstract its oxygen, and chlorine, iodine, &c., the hydrogen. Grove (*Chem. Gaz.* iv. 406) affirms, however, that he has succeeded in decomposing water solely by heat. For other properties, see HYDROGEN and the heads referred to in this article.

Water for convenience of description may be classified as follows:—

1. *Rain Water.* This, as well as that from snow, are the purest, next to distilled water. Their impurities are the matters soluble in water with which the atmosphere is charged, and consist of very minute quantities of carbonic acid, carbonate of ammonia, chloride of sodium, organic and suspended mineral matters. When the rain is accompanied by electrical discharges it is said to contain also traces of nitric acid and nitrates. Snow water, according to chemists, is richer in oxygen than other water.

2. *Spring or Fountain Water.* This varies in purity with the nature of the soil which it traverses. It may very properly be classed with—

3. *River Water.* Is next in purity to rain water, but contains saline and other ingredients in variable proportions. When lime or chloride of sodium is a prominent component, the waters are termed *hard* because of their peculiar taste and property of decomposing or rendering insoluble the soap used in washing.

4. *Sea Water.* Is highly charged with salts, and distinguished by its bitter, disagreeable, saline taste. See table of analyses, p. 946.

5. *Mineral Waters.* These are very variable in their composition, some containing but few, and others many ingredients. Strictly speaking, all waters holding mineral matter in solution, without regard to the proportion, belong to this class; but in the usual acceptance of the term, it embraces only those which are highly impregnated. Sea water and the like may, therefore, be included under this head. When chloride of sodium is present in sufficient quantity to render its extraction profitable, the waters are called *salines*. *Calcareous* waters are those in which lime is largely present, the term *selenitic* being applied to those in which the lime exists as sulphate. Mineral waters are also styled *magnesian*, when magnesian salts give them their characteristic taste and properties; *hepatic* or *sulphurous* when they contain appreciable quantities of sulphuretted hydrogen or soluble sulphurets; and *chalybeate* when carbonate of iron (rarely sulphate) is the characteristic constituent. *Acidulated* waters are those in which the salts are bicarbonates, and which therefore contain free carbonic acid. *Thermal* waters from "hot or warm springs" owe their high temperature to old but continuous, or recent volcanic influences. Many of these mineral waters, as before said, contain ingredients which render them eminently medicinal. Some are applicable to one, and others to another class of disease, according to the therapeutic properties of their ingredients, and hence the mineral springs of accredited virtues are famous resorts for invalids.

The "mineral water" of the shops is nothing more than water surcharged with carbonic acid, and sweetened with syrups of different flavors. For exportation this water is drawn direct from the fountain and immediately corked with fastenings. The machinery for the purpose is described by Souberain in his "*Traité de Pharmacie*." For the convenience of those unable to be visitors, the waters of mineral springs are bottled up and exported; and the art of imitating natural waters by artificial means has been successfully carried out in Germany and other countries. Some of them, however, undergo change by time and transportation.

Souberain in his "*Traité de Pharmacie*" gives the most approved methods in detail. The first step is to ascertain by accurate analysis the ingredients of the original water, their exact state of existence and proportion. This being done, if the water is a mere solution of saline matters, it is to be compounded accordingly of pure water, and the constituents in proper ratio. Should some of the ingredients be insoluble or nearly so in themselves, as is frequently the case, time, aided by machinery, is required to effect their solution. In most instances, however, the insoluble salts may be incorpo-

rated with the water by generating them therein by double decomposition. The bicarbonated waters are made by using carbonates without regard to solubility, and impregnating the waters with carbonic acid by means of a force pump. The insoluble carbonates are thus converted into soluble bi-salts. Waters of this kind are called "*acidulated salines*." Feruginous waters must be prepared with water freed from air by boiling, otherwise the iron may become peroxidized and insoluble. The sulphuretted waters contain sulphur in the form of sulphuretted hydrogen, or in combination with alkaline bases, and are prepared by saturating the simple solutions with sulphuretted hydrogen gas.

Action of water upon metallic vessels and conduits.

As the population of cities and towns increase, so also augments the necessity of an increased supply of potable water, and as wells afford but a limited amount, some more inexhaustible source must be found. Neighboring streams are most generally tapped for this purpose, and as the pipes in which the water is conducted and used are metallic, it is, as affecting the public and private hygiene, a duty to inquire how far the constituents of the water are prejudicial by reason of their chemical action upon metal.

In a majority of cases, where iron pipes are employed, the water is not in the least affected, or so slightly as not to be in the smallest degree prejudicial. The convenience of setting flexible lead-tubes, together with their cheapness, has introduced them into general use for conducting water through short distances. Experience has shown that nearly all fresh-

river water, and the water of most springs, will not be seriously affected in leaden pipes of 100 yards length, which is much longer than is usually employed. Spring and creek water flowing from metamorphic rocks may be generally relied upon, unless they happen to be too pure, as suitable for leaden pipes. We have not sufficient experience to pronounce upon limestone waters with certainty, but there is every ground for asserting that they may be passed through leaden pipe with impunity, since such waters deposit notable quantities of sulphate of lime. It is from well and spring waters of alluvial and modern formations that we have most to fear in the use of leaden pipe; for experience has shown that notable quantities of lead are dissolved by waters of this character, and the health of many persons has been seriously affected by the free use of the water. In one such case, the remedy proposed by the author was successful, although the length of pipe was 3000 feet. Many experiments have been made on this subject with more or less success by Christison, York, &c., but until a large number of waters shall have been minutely analyzed, of those which have proved injurious and those which have not, where lead pipe has been employed, no sound generalization can be given. See LEAD. Solid tin pipe is too costly, and lead pipe internally coated with tin is too uncertain to be implicitly relied on for universal employment.

The first of the following tables presents a view of several ocean waters, and of inland seas. The second and third tables present a complete view of many saline springs, from Ure's Supplement, drawn from a German source.

Analyses of Sea Waters.

	1 Elton Lake	2 Dead Sea.	3 English Channel.	4 Black Sea.	5 Azof.	6 Caspian.	7 Mediterranean.
<i>Specific gravity</i>	1.27288	1.22742		1.01365	1.0097	1.00539	
Chloride of sodium.....	38.3	78.554	27.00	14.019	9.658	3.673	2.94
“ “ potassium..	2.3	6.586	0.77	0.189	0.128	0.076	0.05
“ “ magnesium	197.5	145.897	3.67	1.303	0.887	0.632	0.32
“ “ calcium.....		31.075					
Bromine salt		1.374	0.30	0.005	0.003		0.05
Sulphate of lime.....		0.701	1.40	0.105	0.288	0.490	0.13
“ “ magnesia..	53.2		2.30	1.470	0.764	1.239	0.24
“ “ potassa....							
Carbonate of lime.....			0.33	0.359	0.022	0.171	0.01
“ “ magnesia				0.209	0.129	0.013	
	291.3	264.187	35.77	17.659	11.879	6.294	3.74

1. Analyzed by H. Rose. Göbel's analysis of the same gives less magnesian and more sodium chloride. 2. Analyzed by J. C. Booth and A. Mucklé, quoted from report to Congress, Feb. 1849, made by Lieut. W. F. Lynch, U. S. N. who commanded the late expedition to the Jordan and Dead Sea. An interesting report on the geology of that region may be looked for from H. J. Anderson, M. D., the geologist to the expedition. Calculated by the later determinations of equivalents, the numbers will vary slightly from those in the table. It is also

probable that the determination of bromine is too high, from the impracticability of determining it accurately in the presence of such a large excess of chlorine. 3. By Schweitzer. 4, 5, and 6, by Göbel. 7. By Usgilio. Wollaston found that taken from a depth of 400—450 ft. in the Mediterranean its spec. grav. was 1.0295, and it contained 4 pr. ct. saline matter; at a depth of 670 feet it was 1.1288, and its saline content 17.3 pr. ct. Clemm's and Soltmann's analyses of the water of the German Ocean give 31.87 pr. ct. of solid matter.

TABLE I.—THE MOST IMPORTANT MINERAL WATERS OF WURTEMBERG.

Classification.	Places.	Specific Gravity and Temperat.	Quantity.	Gases.			Carbonated Salts.				Muratic Salts.			Sulphuric Salts.			Other Constituents.	Total.	Authors.		
				N. O.	CO ₂	SH.	Iron-oxide.	Soda.	Lime.	Magnesia.	Soda.	Lime.	Magnesia.	Soda.	Lime.	Magnesia.					
1. Fer- riferous Waters	Bierach, (Moorgrund in Mo- lase)	1.000206 80°	10000 grammes.	N + O 7.002 cub.in.	63.025 p. 3 cub.in.	cub. in. = 16 oz.	gr. 0.262 = in 16	gr. 0.19 oz.	gr. 2.380 = 1.83	gr. 0.344	Traces.	gr.	gr.	gr.	Silica, 0.084 gr. Organic Mat. 2.34 gr. in 16 oz.	{ 307 = 234 gr. in 16 oz. 15.794, 33-31 173-16 25-4762 25-1535 134-2, 95-3 56-631 13-59 56-071 7-88 24-48 18-40 18-05 77-1443 2-326 3-649 11-569 8-74 6-128 11-57 8-07	{ C. Gmelin & Mayer, Gmelin & Schulz. Sandel.				
	Crailsheim (Keuper)	80°	16 oz.		25.1 c. in.	Traces.	0.109		3.674			0.082	1.351	8.214	2.272			Sulph. of Pot. 0.433 gr. Sulphur, 0.059 gr.			
	Offenhau (Muschelkalk)	10°-49°	16 "		2.765 "		0.035		1.32			157.44	0.62	0.67	1.44			9.12	1.44	Organic matter, 0.41 gr.	
2. Saline.	Hall (Muschelkalk)	10°	16 "						1.69												
	Rottenmunster. (Brine spring of Wilhelmshall)	1.19553 Spec. grav.	100 pts.						0.0224				0.3919	24.5537							
	Schwennungen. (Brine spring of Wilhelmshall)	1.19776 Spring	100 "										0.0254	24.1682							
3. Ther- mal.	Mergentheim (Muschel- kalk)	1.012	16 oz.		13.53 "		Traces.		3.26			Potash. 0.38		78.42	16.50	2.70				{ C. Gmelin, 1829. Wrede, 1836. Federhaff.	
	Calw. Artesian Spring (Bunter Sandstein)	8-50° 1.00265	100 "		8.033 "		0.02		4.10	0.33	45.10		7.00	30.36	7.43	0.86	Mineral Resin, 0.10 gr. Traces of Silica.				{ Sigwart & Weiss. Degen. Naschold.
	Wildbad (Old Spring Granite)	5-10° 1006	16 "		21.138 "		0.668	6.991	20.95	2.35	2.811	4.724	0.569	2.809	Nitrate of Pot. 13.039		Sulph. lime, 0.460 gr. Silica, 1.26 gr. Ex- tractive matter, 0.20 gr. Sulph. potash, 0.39 gr. A little manganese				{ Sigwart & Weiss. Degen. Naschold.
4. Cold neu- tral.	New Spring, 1836.	27-37° 26.5	100 pts.				0.2	0.53	0.34	0.70	1.82			0.40			Silica, 0.39 gr. A little silica, 0.638 gr. A lit- tle manganese				{ Sigwart & Weiss. Degen. Naschold.
	Liebenzell (Bunter Sand- stein and Granite)	1001.3 17.5-19.5°	16 oz.	44.17+5.25 100 43 + 18 100	51.58 " 39 " 100	Traces.	0.10	0.50	0.82		5.14		Traces.	0.61			Silica, 8.41 gr.				{ Sigwart. Sigwart. Sigwart. Zwink.
	Tubingen (Wilhelmsstifts- brunnen, Keuper)	10°	16 "		1.3 "				2.56	16.00	1.12			2.40	Potash. 2.40		Traces of Mur. of Soda, Magnesia, and Silica				{ Sigwart. Sigwart. Sigwart. Zwink.
5. Acidu- lous Waters.	Lowenstein (Theusser Bad, Keuper)	10°	16 "		0.06 "				1.97	0.95			0.35	1.1	11.28	2.75	Resinous Extract. . . .				{ Sigwart. Sigwart. Sigwart. Zwink.
	Moglingen (Christen- hof-Lias)		16 "		0.06 "				2.85	0.57			0.46	0.86	10.31	2.85	Traces of Carbonate of Iron and Resin 0.3967 gr. Sulph. Potash, 0.3967 gr. Traces of Resin, Iron- oxide, Phosph. acid, and Silico-fluoric acid, with Humus, 1.3750 Lime				{ Zwink.
	Riettau (Keuper)		100 "		21.8737 100				16.4062				2.7615	2.9192	18.750	8.4107					{ Zwink.
5. Acidu- lous Waters.	Gieszen by Brenz. (Jura with Torgrund)	1.0005 6.80°	16 "	0.32+0.06 cub. in.	2.68 "			0.019	2.031	0.166	0.021	0.009	0.049		0.061		Silica, 0.09 gr. Humate of Alumina, 0.065 gr.				{ Salzer.
	Ulm (Griesbad)	5-6.5°	16 "		30.551 " 100				1.625	0.105			1.875				Traces of Nitric and Sul- phuric Salts				{ Leube.
	Imtau (Prince's Spring)		16 "	N O = atm. air.	27.119 " 100		0.044		6.855	0.089	1.044		0.326		0.221	0.335	Silica, 0.029 gr. Organic mat. 1.120 gr.				{ Sigwart.
5. Acidu- lous Waters.	Second lower spring		16 "	> atm. air.	27.531 " 100		0.564		6.629	0.429	0.078		0.045		0.487	0.140	Silica, 0.092 gr. Organic mat., 0.430 gr.				{ Sigwart.
	Fifth lower spring		16 "	> atm. air.					4.166	0.336	0.124		0.138		0.157	0.381	Silica, 0.205 gr. Organic mat., 0.622 gr.				{ Sigwart.
	Niedernau (Old Springs Muschel- kalk)	11-12°	16 "		1.21 V.	Traces.	0.08		7.44	0.86			0.58	0.28	Potash. 1.02	1.18	Silica, 0.12 gr. Oxidu- lated mang., 0.01 gr.				{ C. Gmelin Sigwart.
	Carls Springs	60.8	16 "		14 cu. in.		Traces.		5.807	1.637			0.214			0.402	Asphalt, 0.010 gr.				{ C. Gmelin Sigwart.

TABLE I.—THE MOST IMPORTANT MINERAL WATERS OF WURTEMBERG.—Continued.

Classification.	Places.	Specific Gravity and Temporal.	Quantity.	Gases.			Carbonated Salts.				Muriatic Salts.			Sulphuric Salts.			Other Constituents.	Total.	Authors.	
				N. O.	CO ₂	SH.	Iron-oxide.	Soda.	Lime.	Magnesia.	Soda.	Lime.	Magnesia.	Soda.	Lime.	Magnesia.				
5. Acidulous Waters.	Niedernau (Muschelkalk)	.....	14 oz.	.....	29 cub. in.?	.....	0.10432	.....	3.75	0.33571	.....	0.24438	.....	With Potash, 0.03571	.....	0.13326	Silica, 0.10714 gr. Extract, with Petroleum, 0.07857 gr.	5.02372	Ritter.	
	Sulzerrain (Zollerische Quelle)	15.50	16 "	.....	23.12 "	.....	0.16	.....	7.00	0.05	19.75	.....	.....	6.50	8.25	3.50	Sulph. Potash, 0.50 gr.	46.34	Morstatt.	
	Frosner.	.....	16 "	.....	19.28 "	.....	0.11	.....	8.68	.....	15.00	0.25	0.12	3.75	8.38	2.38	.....	38.68	.....	
	Gannstalt (Muschelkalk und Keuper)	160	16 "	.....	19.50 "	.....	0.25	.....	7.38	0.31	16.75	0.25	0.18	4.75	7.75	2.25	.....	39.87	.....	
	Wirtschel zum Ochsen	.....	16 "	.....	13.00 "	.....	Traces.	.....	4.100	Traces.	7.00	.....	.....	2.40	3.00	0.78	.....	17.18	.....	
	Water . . .	16.30	16 "	.....	15.55 "	.....	0.231	.....	9.100	0.475	19.711	.....	0.272	2.679	8.775	2.617	Sulph. Potash, 0.386 gr.	44.24	.....	
	Neckarinsel Stad.	15-160	16 "	.....	21 "	Traces.	33.35	20.58	1.41	Traces.	18.50	.....	0.37	8.25	32.95	1.00	Silica, 0.31 gr. Organic mat., 25.40 gr.	120	Sigwart.	
	Berg (Muschelkalk und Keuper)	1.00548	16 "	.....	22.1 "	Traces.	0.25	8.00	.....	Traces.	18.15	.....	0.25	6.25	7.25	4.33	.....	43.62	Morstatt.	
	Kunst-schekalk muble.	140	16 "	.....	.....	.....	0.14	9.00	.....	0.25	.....	.....	.....	6.06	.....	.....	.....	44.37	.....	
	Privil. Fabrik der Insel	.....	100-000 parts.	.....	.....	.....	With Alumina 4.29	.....	110.18	8.10	205.79	.....	.....	0.92	81.68	65.56	.....	476.53	Degen.	
6. Sulphurous Waters.	Dachleins kasten	7.50	16 oz.	.....	20.67 "	.....	Traces.	2.2387	3.4380	0.3979	0.3024	.....	Traces.	0.6559	.....	.....	Silica, 0.2905 gr.	7.3254	Federhaff.	
	Teinach (Bunter Sandstein)	6.50	16 "	.....	0.213 "	.....	With Mangan. 0.1216	0.4144	0.5376	0.0800	0.3152	With Potash and Magn.	.....	Potash and Lime with Soda, 0.020	.....	.....	Silica, 0.0422 gr.	1.5120	.....	
	Ueberkingen (Jurakalk with Eisenogestein)	90	16 "	.....	19.5 "	.....	0.072	0.390	6.827	0.247	.....	.....	.....	0.276	0.020	0.056	.....	7.888	Leube.	
	Dizenbach (Jurakalk)	70	16 "	.....	27.7 "	.....	.....	3.6096	.....	.....	0.0199	.....	.....	0.0960	.....	Traces.	Organic matter, with Sulphur, 0.0184 gr.	3.7379	C. Gmelin.	
	Boll (Bismioser Mergelschiefer)	1.00137	16 "	N. 0.0134 V. of water	0.003 V. to 0.006	0.1705 V.	Potash. 0.03	1.03	1.44	0.03	0.22	.....	.....	3.34	.....	.....	Silica, 0.05 gr. Asphalt.	6.19	.....	
	Kirchheim under Teck (Lias-schiefer)	7-80	16 "	.....	Under-mined.	.....	.....	0.77	0.60	0.29	0.34	.....	0.67	0.58	Traces.	.....	Silica, 0.06 gr. Sulphur 0.021 V. Asphalt, mat., 0.57 gr.	4.58	Muschler.	
	Reutlingen (Lias-schiefer)	9-100	16 "	N. 0.015 V.	0.087 V.	0.029 V.	0.02	0.93	0.35	1.05	0.40	.....	.....	0.49	.....	.....	Carburetted Hydrogen, 0.021 V. Asphalt, mat., 0.57 gr.	4.96	{ Sigwart & Vobringer	
	Seebadweiler (Lias-schiefer)	9-110	16 "	N. with 3.07 per ct. Acid Gas.	CO ₂ Carb. 2.26-4.33 p. ct. V.	0.0564 V.	0.06	.....	3.72	0.41	0.59	.....	0.23	4.51	Trac. of Potash with Lime.	1.61	Silica, 0.18 gr. Traces of Iodine and Manganese. Asphalt, 0.92 gr.	11.33	Sigwart.	
	Hechingen (Lias-schiefer)	8-90	16 "	.....	Under-mined.	.....	.....	.....	3.0878	1.2296	.....	.....	0.5181	3.4821	0.2167	1.4971	Sulph. Potash, 0.0187 gr. Silica, 0.04657 gr.	10.1874	C. Gmelin.	
	Reichheim near Morkmühl (Muschelkalk)	9.5-100	16 "	.....	1.00 V.	0.27 "	0.03125	.....	1.7825	0.31125	0.24632	.....	Alum. 0.00625	0.34341	0.4575	0.34083	Silica, 0.04657 gr. Clay with Phosph. Acid, 0.05. Extractive, 0.13875 gr.	4.7830175	{ Sigwart & Heufel	
7. Saline Waters.	Neustadt-chausen a. d. Rems.	1.0005	16 "	.....	Insig-nificant.	.....	0.44	.....	2.184	0.23	.....	.....	0.17	.....	0.456	0.33	Silica, 0.102 gr. Traces of Organic matter	3.869	C. Gmelin.	
	Water . . .	9.70	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Quartzsand, 6.21 gr. Organic matter, 1.56 gr. Alum., 1.107 gr. Loss, 0.03 gr.	20.0	.....	
	Dried Mud . .		20 gr.						0.5	0.38										
8. Spring Waters.	Winterbach (Keuper)	8-90	16 oz.		2.0 cub. in. Under-mined.	28 cub. in.	Iron-oxide. 0.37		0.235	0.143	0.285	With Magn.			1.567	1.142			3.422	Sig. & Buhl.
	Second Spring.	8-90	16 "			0.07 "		0.25	0.55		0.83		0.25		1.66	0.55			4.09	Gruenzweig.

TABLE II.—THE MOST IMPORTANT MINERAL WATERS OF GERMANY.—Continued.

Classification.	Places.	Specific Gravity and Temperat.	Quantity.	Gases.		Carbonated Salts.				Muratic Salts.			Sulphuric Salts.			Total solid Parts.	Authors.	
				N. O.	CO ₂	Iron-oxide.	Soda.	Lime.	Magnesia.	Soda.	Lime.	Magnesia.	Soda.	Lime.	Magnesia.			
b) Alkaline saline Chalybeate Waters.	Marienthal, Fendelsquelle (porphyritic Grant)	1-0046 7-50° R.	oz.	.....	13-736	0-3993 0-082 Mang.	6-1302	4 0112	3-0489	8-9963	.....	.....	.....	gr.	gr.	Carbonate of Lithia, 0-0676 Strontia, 0-0054 Phosphate of Alumina, 0-0054 Silica, 0-75 Phosph. Extractive (Potash 0-23 & lime. Resin, 0-50) Traces.	45-962	Berzelius.
	Geddelheim, Stahlquelle (Braunkohlenager)	.....	.....	.....	40-0	1-75 0-16 Mang.	.....	2-75	1-25	6-50	0-50	0-50	2-50	2 00	1-75	.....	21-11	Witting.
	Schwalbach, Weinbrunnen.	1-001 9° R.	16	.....	22-0 cub. in	0-66351	0-50000	1-63649	4-24324	0-25225	.....	0-20270	0-37837	0-48648	.....	Alumina, 0-32432	8-6873	Rube.
	Königs- warth, Trink- quelle (Basaltgebirge with Torgern)	.....	.....	.....	151-37 100	0-431	0-443	3-238	.....	0-047 0-062 P.	.....	.....	0-089 Pot.	.....	.....	Subphosphate of Alumina, 0-19 Silica, 0-653. Humic Acid, 0-157	6-772	Steinmann and Berzelius.
	Cudowa, Trinkquelle (Urgeb. and Sandstein)	1-006 7-50° R.	16	.....	43-0	0-5062	12-1325	1-8713	13-614	1-9492	.....	.....	4-3508	.....	.....	Extractive, 0-8654	35-6894	Kneiser.
	Reinerz, tepid Spring (Urgebirge)	1-02 14° R.	16	.....	20-28	.....	13-850	5-200	1-340	0-560	.....	.....	2-027	.....	.....	Potash and Manganese, carbonate of iron in the cold springs.	22-977	Mogalla and Gauthier.
	Niedelangenau (Quadersau)	.....	16	.....	30-7	0-421	0-871	0-947	0-115	2-720	.....	1-767	0-132	.....	.....	.....	7-973	Trommsdorff.
	Steben (Thonschiefer)	1-002	16	.....	27-5	0-65	0-75	1-65	0-20	0-08	.....	.....	0-05	.....	.....	Humic Acid, 0-12 Silica, 0-5	4-40	Vogel. Fauke
	Tonstein (Trass)	7-50° R.	16	.....	21-04	0-10	7-25	9-00	.....	0-95	.....	.....	0-80	.....	.....	.....	18-10	Stuke.
	Willenzen, Thabrunnen (Uebergangs- birge) Freudenthal (Maximiliansquelle)	1-0011 8° R. 6° R.	16 16 16		21-33 49-62	0-500 0-26		2-500	2-213	0-125	0-065			0-17			Silica, 0-13 Sulphate of Manganese, 0-328 Resin, 0-4-6. Silica, 0-169	6-165	Scholz.
c) Earthy- and Copper- sulfur- holding Chalyb. Waters.	Alexisbad, Selkenbrunnen	6-5 R.	.....	.....	.....	0-574 Sulphuretted Oxide. Iron.	.....	.....	1-083 Oxide of Iron.	.....	0-281	0-675	0-739	0-651	.....	Alumina, 0-380. Oxide of Iron, 0-16 Strontia, 0-20. Extractive, 0-120 Ex- trac- tive, 0-005	4-876	Trommsdorff.
	Bukowina, Nieder- quelle	9-5 R.	.....	.....	.....	1-960 Sulphuretted Oxide. Iron.	.....	.....	0-920 Oxide of Iron.	.....	.....	0-480	.....	2-080 Alumina	.....	Alumina, 0-380. Oxide of Iron, 0-16 Strontia, 0-20. Ex- trac- tive, 0-120 Ex- trac- tive, 0-005	6-220	Lachmund.
	Bilin, Josephsquelle (Klingsteinporphyr)	1-00853 9-10° R.	16	0-215 cub. in.	33-58	0-949 0-011 Mangan.	23-948 8-88 Lithion.	2-349 0-014 Strontian.	1-976	2-927	.....	.....	5-539	1-891 pot.	.....	Subphosphate of Alumina, 0-014 Silica, 0-088 Phosphate of Soda, 0-0186. Silica, 0-087. Nitrate of Magnesia 20-274	39-204	Steinmann.
	Fachingen (Thonschiefer)	8° R.	16	.....	19-6874	0-082	43-2578	2-4965	1-7313	4-3119	.....	.....	0-3886	.....	.....	.....	52-3762	Bischof.
	Sieckelutz, Hauptbrunnen (Volcanic Formation)	1-01761 16-40° R.	16	0-105	3-304	0-108 0-028 Man- gan.	0-0-4 Strontian.	4-838	1-100	.....	2-606	27-113	2-496 22-552 Pot.	.....	78-753	Subphosphate of Alumina, 0-018 Silica, 0-061. Humic Extract, 0-385	160-718	Steinmann.

	70° R.	Dried Salts.	6-939	.....	0-1750 0-0384	7-1332 0-1144	.....	0-770	6-406	.....	16-666	129-900	2-6 4-8 Pot.	93-086	Subphosphate of Sulphur, 0-176 Subphosphate of Alumina, 0-031 Silica, 0-3875	Struve.
Fullna, Bitterwasser	1-00941	16	8-384	.....	0-1750 0-0384	7-1332 0-1144	.....	0-770	6-406	.....	16-666	129-900	2-6 4-8 Pot.	93-086	Subphosphate of Sulphur, 0-176 Subphosphate of Alumina, 0-031 Silica, 0-3875	Struve.
Marienthal, Kreuzbrunnen (porphyritiger Granit)	9-59 R.	16	100	.....	0-065 with Mangau.	6-238	.....	0-065	2-7187	.....	13-5636	38-1158	.....	.....	.....	Berzelius.
Pymont, saline Spring (junster Sandstein)	1-0112	16	100	.....	0-065 with Mangau.	6-238	.....	0-065	.....	.....	.....	12-246	5-516	0-087 L.	Resin, 0-100	Brandes.
Elmen near Schonbeck.	8-50 R.	16	Undermined.	.....	0-025	.....	.....	0-065	.....	.....	146-98	1-800 0-120 Pot.	2-480	0-300	Resin, 0-08615, Fluoride of Soda, 0-01453	Herrmann.
Brue spring (Kalkstein)	.....	16	.....	.....	0-025	.....	.....	0-065	.....	.....	146-98	1-800 0-120 Pot.	2-480	0-300	Resin, 0-08615, Fluoride of Soda, 0-01453	Herrmann.
Neundorf, Trinkquelle (Muschelkalk)	1-003	16	1-31 cu. in. 1-46 SH.	.....	0-0062825	0-007177	.....	1-707539	0-865046	0-985476	.....	0-549313	7-292164	0-797390	Alumina with Silica, 0-011453	Wurzer.
Ischl, Brine (Salzformation)	.....	16	.....	.....	0-025	.....	.....	0-065	.....	.....	146-98	1-800 0-120 Pot.	2-480	0-300	Resin, 0-08615, Fluoride of Soda, 0-01453	Wurzer.
Kissingen, Ragotzbrunnen (Flotzkalk und Sandstein)	8-5-9-50 R.	16	36-25 cub. in.	.....	0-068 with Mangau.	0-82 with traces of Lithion.	.....	3-55 with traces of Strontia.	2-50	62-05	0-91 Pot. 0-05 Am.	4-855	1-027	1-820	Phosphate of Soda, 0-17, Extract, 0-5	Kastner.
Baden Baden, Hauptquelle (Flotzkalk)	43-5-40 R.	16	0-333 cub. in.	.....	0-111	.....	.....	1-500	17-500	0-500	.....	.....	2-75	.....	.....	.....
Wiesbaden, Krichbrunnen (Thonschiefer)	1-0047	16	N. CO ₂ = 54: 46	.....	0-078	.....	.....	1-650	0-700	44-225	5-489 1-200 Pot.	0-790	0-42	.....	Extractive, 1-750 Silicate of Magnesia, 0-600	.....
Enns, Kesselbrunnen (Ueberrauschgebirge)	37-40 R.	16	.....	.....	0-0625 0-250	20-0000	.....	2-0000	3-0000	0-5000	0-2500	1-0000	.....	.....	.....	.....
Schlangebad, alter Brunnen (Thonschiefer)	1-00055	16	1-875	.....	.....	3-25	.....	.....	1-10	.....	.....	.....	.....	.....	.....	.....
Teplitz, Hauptquelle (Urgeb. und Basalt)	39-50 R.	16	2-4	.....	0-036	12-240	0-340	0-776	.....	.....	.....	1-696	.....	.....	Resin and extractive, 0-1, Silica, 0-42	Ambrozi.
Gasstein (Urgebirge)	37° R.	16	.....	.....	0-0434 0-0138	0-0597	0-3894	0-2834	0-0100	.....	.....	1-4331 0-6292	.....	.....	Phosphate of Alumina, 0-0292	Hunefeld.
Carlsbad, Sprudel (Urgeb. und Basalt formation)	35-40° R.	16	11-85	.....	0-0278 0-0434	9-69500	.....	10-0-005 0-0-005	1-36865	7-97583	.....	19-89916	.....	.....	Silica, 0-57715-Fluor spar, 0-02458	Berzelius.
Berrich (Grauwack-esschiefer)	1-0165	16	0-1	.....	0-480	0-740	0-720	0-080	1-200	.....	.....	8-160	0-560	0-860	Subphosphate of Alumina, 0-0 246	Mohr.
Hottest non-sulphurous Spring	1-004	16	7-60	.....	0-055 Strn.	6-722	0-395	0-242	22-057	0-573 Flr. Spar.	.....	3-465	.....	0-656 Silica)	Phosphate of Soda, 0-161	Monheim.
Burt-scheid (Ueberkalk)	62°	16	.....	.....	0-042 Strn.	6-599	0-241	0-113	21-615	0-485 Flr. Spar.	.....	2-567 0-624	.....	0-553 Silica)	Animal mat., 0-32 Phosphate of Soda, 0-142, with Lithia, 0-0005	.....
Sulphurous Trunkquelle	1-001	16	7-712	.....	0-042 Strn.	6-599	0-241	0-113	21-615	0-485 Flr. Spar.	.....	2-567 0-624	.....	0-553 Silica)	Animal mat., 0-32 Phosphate of Soda, 0-142, with Lithia, 0-0005	.....
Aachen, Kaiserquelle (Ueberkalk mit Thonschiefer)	1-004	16	8-00	.....	0-043 Strn.	6-610	0-232	0-152	20-716	0-470 Flr. Spar.	.....	2-121 0-610	.....	0-540 Silica)	Animal mat., 0-294	.....
Warmbrunn, Grafenbad (Urgebirge)	37-46° R.	16	8-00	.....	0-043 Strn.	6-610	0-232	0-152	20-716	0-470 Flr. Spar.	.....	2-121 0-610	.....	0-540 Silica)	Animal mat., 0-294	.....
	30 R.	16	.....	.....	.....	5-072	1-101	0-833	.....	.....	.....	2-814	0-463	.....	Resin, 0-605	Tschoner.

TABLE II.—THE MOST IMPORTANT MINERAL WATERS OF GERMANY—Continued.

Classification.	Places.	Specific Gravity and Temperature.	Quantity.	Gases.		Carbonated Salts.				Muriatic Salts.				Sulphuric Salts.				Other Constituents.	Total solid Parts.	Authors.
				N. O.	CO ₂	Iron-oxide.	Soda.	Lime.	Magnesia.	Soda.	Lime.	Magnesia.	Soda.	Lime.	Magnesia.					
4. <i>Alcaline Waters.</i>	Oestr. Baden (Flotzkalkstein)	1-004 29-30 R.	16	SH. 3-33	1-77												Silica, 0-012	gr.	2100	Schenk.
	Lanck, St. Georgenbad (Guens)	23-50 R.	16	SH. 4-333	1-25												Alumina, 0-1, Silica, 0-016		1-897	Mogalla and Gunther.
	Selters (eisenhaltige Thonlager)	1-00369 14° R.	16		15-57	0-1542 with Mangau.	15-4093	1-8672	1-5953	16-2855	0-066						Phosphate of Soda, 0-7233		36-8893	Bischoff.
	Rosdorf, Trinkquelle	1-00449 9-50 R.	16		19-86	0-0557 with Mangau.	6-0406	2-1657	3-0628	14-5997							Phosphate of Soda, 0-505		20-7797	
	Schwalheim (Basalt)	1-0022 8-50 R.	16	N. 0-367 O. 0-122	37-55	0-191377	0-775683	4-254243		0-777800	0-581530 Pot.						Silica, 0-1240. Alumina, 0-008		17-260307	Wurzer.
	Kissingen, Maximiliansbrunnen (Flotzkalk and Flotztrapp)	9-50 R.	16		30-24		0-85	2-70	1-82	18-24	1-02 Pot.	3-05	1-85	0-77			Phosphate of Soda, 0-12. Traces of Hydrobromate of Magnesia		30-39	Kastner.
5. <i>Sulphurous Waters.</i>	Soden, Winklerbrunnen	1-00742 14° R.	16		18-569	0-253 with Mangau.		5-068	3-847	40-611	0-407 Pot.			0-322			Alumina, 0-029. Silica, 0-029		51-171	Schweinsberg
	Salzherrn, Oberbrunnen (Uebergangsbirge)	1-00241 5-60 R.	16		98	0-018	8-010	2-003	1-001	1-012							Bromine and humic Salts			Fischer.
	Frauenbad, kalter Sprudel (vulkanische Gebirge)	1-00588 9-30 R.	16		39-4	0-2000 0-0040 Mang.	7-1733	1-6000 0-0013 Strn.	0-0133	8-6000							Silica, 0-0240 and Magnesia		44-6079	Trommsdorff.
	Frymont, acifluous, (bunter Sandstein)	1-0001 8-30 R.	16		83-5		0-3062	1-8110	0-1684	0-0118			0-1262	0-3752	0-3156	0-6030	Traces of Lithia, Rhyta, and Strontia		3-7284	Brande.
	Sironabad (Basalt)		16		100	0-042	0-226	0-883	0-037	1-970			0-214	1-364	0-209		Extractive { Resinous, 0-053 Salphurous, 0-069, 0-069 }		5-067	Buchner.
	Weilbach	150 R.	16	SH. 4-0	9-0		4-500	2-125	1-250	0-750			0-930	1-125			Sulphurous Resin, 0-375		11-055	Creve.
	Nemndorf, Spring under the Vault (Steinkohlenlager)	1-0032 80 R.	16	N. 0-72 SH. 1-19	2-61	0-135198 with Mang.		2-690182	0-418832	0-799002			0-782087	5-187053	7-635612	0-708092	Azole, 0-0321195, Sulphur, 0-008054		18-467790	Wurzer.
	Eilsen, Georgenbrunnen (Muschelkalk & Schieferthou)	1-00373 9-10 R.	16	SH. 7-68	6-72			1-400 Sulphuretted Hydrogen.	0-264	0-338	0-462	1-200	5-726	12-066	3-000		Extractive, 0-066 Azole, 0-132 Alumina, 0-066		35-847	Westrumb.

Meinberg, Schwefel- quelle (Schwarzes Moortümpfer)	75-13° R.	16	N. 141 O. 0.08 SH. 2.13	8.11 100	0.0080 with Mangan.	.....	0.1723	.....	5.844 0.0077	8.353 3.057 Pot.	1.733 0.008 Stromt.	Subphosphate of Alu- mina, 0.06 Silica, 0.12. Animal matter	19-4594	Brandes.
Winslar Sulphur Spring	100.05 11° R.	16	SH. 15.0	10.0	.....	0.500	.....	.....	2.750	17.166	5.125	Alumina, 0.100. Sil- ica, 0.150	28 616	Usinger.
Langensalza	10° R.	16	SH. 3.732	1.628	.....	.....	0.650	.....	1.950	11.150	2.000	Sulphur-resin, 0.1. Alumina, 0.25 Silica, 0.15. Extrac- tive, 0.075	20.075	Trommsdorff.
Kreuth, Stinkergraben	9° R.	16	SH. 1.35	2.625	0.125	.....	0.375	.....	0.125	5.875	2.75	Silica, 0.5625. Hu- mus, 0.125	17.00	Vogel.
Boklet, Schwefelquelle (Flotzkalk with Basalt)	1.0085 9° R.	16	SH. 0.2	21.0	0.40	0.25	0.50	0.01 with Potash.	.....	.....	.....	Silica, 0.10	5.00	
Rosenheim	.....	16	SH. 0.1	.....	0.01	0.06	0.05	.....	0.08	.....	.....	Humus, 0.01. Silica, 0.01	1.24	

Classif.	Places.	Authors.	Quant- ity.	Combustible Matters.				Salts.	Oxides.			Classif.	Places.	Quan- tity.	Muriatic Salts.			Sulphuric Salts.			Other Matters, with the Total.	Authors.	
				Sul- phur.	Resin.	Extract- ive.	Fibre.		Iron- oxide.	Silica.	Alum- ina.				Soda.	Line.	Mag- nesia.	Soda.	Line.	Mag- nesia.			
	Elisen . . .	Westrumb	100	4.25	0.12	gr. 6.6 12 Slime.	gr. 6.6 12 Slime.	2.4 } 33.3 Sol. 29.81 Insol.	gr. 3.0 4.0 Hum.	gr. 3.0 cal. careous earth.	gr. 21.36 and with Carbon.	gr. 5.2	Norderney Cuxhaven Fohr	16 16 16	174.000 25.0 179.33	gr. 62.666 25.0 87.0	gr. 1.333 2.0	gr. 8.000 7.0 11.0	gr.	gr.	245.0 240 264.99	Bluhm. Schneisser. Becker.	
	Fistel . . .	Witting .	100	0.75	1.75	3.0 4.0 Hum.	0.5	33.3 Sol. 29.81 Insol.	3.0 4.0 Hum.	3.45 with Mangan.	50.25	3.25	Dusterbrock	16	92.0	Traces of Potash.	30.0	3.5	6.0	Carb. of Lime, 0.4 Resinous mat. 0.5	132.4	Plaff.	
	Gunthersbad	Buchholz	1000		4.0 Wax.	0.75	110.0 Carbon.	155.0 8.60 Soluble.	3.0	92.25 Sand	42.0		Dobberan, Salzquelle.	16	109.502 1.0 Potash.	5.075	16.208	3.782	10.600	9.213	Carb. of Lime, and Magnesia, 4.204 Red Carb. of Iron, 0.35 Extract, 0.88 Silica, 0.200	160-116	Hernstadt.
	Oestr. Baden	Schenk .	240	215.8	.....	.....	.....	15.60 Insol.	9.539	128.139	0.862		Carbonic Acid, 3.572 cub. in. Azote, 0.832 cub. in.										
	Marientbad . .	Steinmann	2128	.....	.....	14.18 Soluble.	8.5367 Combustible with water.	3.61 Soluble Salts.															

But few of the springs in the United States have been thoroughly analyzed; but separate essays are in preparation which will embrace them.

WAVELLITE. *Min.* Subphosphate of alumina, Devonite, Hydrargyrite, Lasionite, Striegosan, Kakoxen. Cryst. Right rhombic, with a perfect rhombic prismatic cleavage; usually in globular concretions having a radiated structure. $H. = 3.25-4$. $G. = 2.337-2.36$. White, passing into yellow, green, gray, brown, black; vitreous, inclining to pearly and resinous; translucent. In a tube it yields water, containing fluoric acid; swells and becomes white on coal; otherwise behaves like alumina; dissolves in acids and caustic alkalies. Form. $Al_2F_3 + 3(4 Al_2O_3, 3 PO + 18 HO)$. Kakoxen has not yet been determined. Peganite belongs rather to calaite. Found in Devonshire, near Cork. From Zbirow, Bohemia; Bellows Falls, New Hampshire.

WAX. *Chem. Tech. Fr. Cire. Ger. Wachs.* The matter excreted by the common bee (*Apis mellifica*), and forming the cell-work of the honeycomb. This product results from the assimilation and chemical transformation, by the vital process, of a portion of the saccharine nourishment of the bee. The honey being separated from the comb by draining and pressure, the residue is to be melted in hot water and cast into blocks. These blocks, freed of the subsident impurities by means of a knife, are hard, yellow, and of a granular structure and peculiar agreeable odor. Fuses at 145° .

Crude wax when exposed in thin ribbons to air, light, and moisture, is blanched and deodorized. In this process it changes its melting point to 158° and congeals at 149° , and according to Lewy it also acquires oxygen and loses carbon. Spec. grav. .960—.966. For the details of the bleaching process and of the mode of making wax candles, see Morfit's "*Applied Chemistry*."

Prop. Wax consists of two substances *Cerin* and *Myricin*, and Lewy adds a third constituent, *Céroléin*. They are separable by boiling alcohol, which leaves the myricin undissolved and drops the cerin on cooling. The *céroléin* may be separated from the mother liquor by concentration. The cerin and myricin are isomeric.

Cerin. $C_{68}H_{68}O_4$. Constitutes the largest portion of wax; crystallizes from alcohol in needles, and melts at 145° ; soluble in 16 pts. of alcohol. By the action of potassa lye, neutral *ceraine* results. It is nearly insoluble in alcohol. The saponified portion of unbleached cerin simultaneously obtained when heated with HCl acid gives *Cerinic acid*, (*Lewy*), which forms white crystals, soluble in absolute alcohol, and melting at 149° . In this saponification no glycerin is eliminated, but, by the substitution of potassa-lime for potassa, Lewy obtained stearic acid. Warington and Francis, who repeated Lewy's experiments, did not realize similar results, but obtained a new body, *Pseudo-ceraine*, analogous to Ettling's *ceraine* (and very closely allied to cerin), differing from it chiefly in fusing at 158° , by greater solubility in hot alcohol, and by forming saponaceous compounds with the alkalies. In a subsequent review of these researches, Lewy attributes this difference to the mode of operating pursued by these che-

mists (*Millon's and Reiset's Annuaire*, 1846), and concludes that wax like fats may be oxidized into stearic and ultimately into margaric acid, and that the only difference between the principles of wax and other fats is that resulting from a more or less advanced state of oxidation.

Myricin. Flocculent, soluble in 200 pts. boiling alcohol and in 99 pts. cold ether. Fuses at 149° . It is isomeric with the cerin of unbleached wax, but not with that of the bleached, for according to Lewy, white cerin contains more oxygen and less carbon than yellow, while the composition of myricin is constant under either circumstances. By the action of potassa-lye it is transformed into *myricinic acid*, fusing at 141° .

Céroléin. Soft and very soluble in alcohol and cold ether. Reddens litmus, and fuses at 83.5° . Its state of oxidation is higher than that of myricin.

Brodie, in recent papers (*Chem. Gaz.* vi. 7), presents a somewhat different view of the chemical nature of wax. He denies the statement of Lewy and Gerhardt that cerin bears the relation to stearic acid of an aldehyde, and pronounces it to be an hydrated acid existing as such in the wax. He calls it—

Cerotic acid, and it may be obtained either by repeatedly crystallizing cerin from ether, or by precipitating its alcoholic solution with alcoholic solution of acetate of lead, and decomposing the resulting compound with acetic acid. The pure acid, $C_{54}H_{54}O_4$, is a volatile, white, brittle, crystalline body, fusible at $174^\circ-176^\circ$. It constitutes 22 pr. ct. of wax. As to *myricin*, Brodie saponified it after some difficulty, and obtained among the products palmitic acid, $C_{32}H_{32}O_4$, and a new wax alcohol, analogous to, but differing from the *cerotin* of China wax. This alcohol he terms—

Melissine. Form. $C_{60}H_{60}O_4$. By oxidation with lime and potassa it becomes *melissic acid*, $C_{60}H_{60}O_4$. Chlorine generates a body of the aldehyde series, analogous to chloral, but with a substitution of between 14 and 15 equivs. of chlorine for hydrogen. In its transformation the alcohol loses 2 equivs. of hydrogen without substitution. Brodie obtained by distillation of myricin palmitic acid and solid *melene* = $C_{60}H_{60}$, melting at 62° .

The conclusions from these researches assign to waxes the same relation to fats as fatty bodies to the alcohol and acetic acid of vinous fermentation, all belonging to a series similar in chemical properties, and capable of analogous metamorphoses.

Action of Heat upon Wax. An undetermined, fatty acid, a carbohydrogen oil, paraffine, and margaric acid are formed by distillation, but no sebatic acid or acrolein.

Action of Nitric Acid. According to Gerhardt, the action of nitric acid produces the same products obtained in the same manner by Laurent from fats.

Vegetable Waxes. Wax, similar to, though not identical with beeswax, exists in many vegetable products; forming the glaucous powder covering certain fruits and the glazed coating of many kinds of leaves. It is also contained in the pollen of some plants, whence it is collected by the bees. Vegetable waxes vary in color, but they may be readily whitened by beating them in fusion with dilute, sulphuric

acid, and agitating the mixture with nitrate of soda. The nitric acid which is thus eliminated in its transit through the mass bleaches it by oxidizing its coloring matters. Of several species; those which have been examined are—

Palm Wax. Formula $C_{36}H_{36}O_2$, (*Boussingault and Lewy*). From the bark of the *Ceroxydon audicola*, growing in New Granada. Yellowish white, pulverulent, and fusible at 161° .

MYRTLE WAX, which see.

China Wax. Syn. *Sinesin*. Form. $C_{36}H_{36}O_2$ (*Lewy*), or $C_{108}H_{108}O_4$ (*Brodie*). Supposed to be the product of the insect *Coccus ceriferus*, which feeds upon the *Rhus succedaneum*. It is white, crystalline, and similar to spermaceti in appearance, but harder and more brittle and fibrous. Fuses at 180.5° , and dissolves in naphtha, from which it crystallizes, and slightly in alcohol and ether. Saponifies by boiling with potassa-lye, but gives no glycerin. Potassa-lime produces *Sinesic acid*, $C_{36}H_{36}O_3$, which melts at 176° (*Lewy*). *Brodie*, on the other hand, gives a different view. By fusion with potassa that chemist obtained a wax acid, forming a soap with the potassa, and another body dissolved in the soap solution, by precipitating with chloride of barium and washing out the dried baryta salt with ether which dissolves out cerotin.

Cerotin. $C_{54}H_{56}O_2$ (*Brodie*). Waxy in appearance, crystallizable, and fusible at 175° . It agrees with the composition of the alcohol of *cerotic acid* existing uncombined in beeswax, and by the action of lime and potassa it yields this acid, which also forms that part of the wax which is rendered soluble by the fusion with potassa.

Chinese wax yields, by distillation, *cerotic acid* and hydrocarbon, resembling paraffin. *Brodie* calls it *Ceroten*, $C_{54}H_{54}$, a crystalline solid, which fuses at 136.4° .

Japan or Tree wax. This, also, is a product of the *Rhus succedaneum*; but *Sthamer* has shown that it is a fat identical in composition with palmitin, from PALM OIL. It contains no olein, but is readily saponified. Hot nitric acid generates succinic acid. Fuses at 104° — 108° .

Chamærops wax. From the *Chamærops humilis*, growing in the West Indies. Falls from the leaves in white powder, and consists, according to *Teschemacher*, of cerin and myricin.

Carnauba wax. $C_{36}H_{36}O_2$ (*Lewy*). Forms the brittle coating of the leaves of a palm tree growing in Ceara and other of the northern provinces of Brazil. Is soluble in boiling alcohol and ether. Fuses at 185° .

Ocuba wax. Extracted by boiling the fruit of the *Myristica ocuba*, *officinalis*, *cebilera*, growing in Para (Brazil), and in French Guiana. It is yellowish white, naturally, but may be perfectly bleached. Is soluble in boiling alcohol, and fuses at 98° .

Ibucuba wax. From Brazil, and analogous to the preceding, being the product of the *Myristica bicuiba* or *bicuhyba*.

Andaques Wax. From the Orinoco and Amazon rivers, and produced by a species of bee. Composition = $C_{24}H_{24}O$ (*Lewy*). Spec. grav. .917 at 0° . Fuses at 170.6° . *Lewy* found it to consist of three different constituents, separable by alcohol in the same manner as cerin and cerolein from beeswax. There are two solid, identical in composition, fusing point, and properties, the first (50 pr. ct.) with

palm wax, and the second (45 pr. ct.) with cerosie or cane wax. The third, or oily matter, forming the residual 5 pr. ct. of the wax, has not been examined.

Cerosie or Cane wax. $C_{48}H_{48}O_2$ (*Lewy*). Detached from the epidermis of the sugar-cane, and is most abundant in the violet variety. It is white when pure, crystallizable, fusible at 179.6° , insoluble in cold, but very soluble in boiling alcohol. Is also insoluble in ether. By union with sulphuric acid, it forms *Sulfo-cerosic acid*. Treated with potassa lime, cerosie yields:

Cerosic acid. $C_{48}H_{48}O_3$ (*Lewy*), or $C_{48}H_{50}O_2$ (*Dumas*). White, crystallizable, slightly soluble in alcohol and boiling ether, and fusible at 200° . According to *Avequin*, one hectare of violet cane yields 100 kilogs. of wax.

WEBSTERITE. See ALUMINITE.

WEHRLITE. It is probably *LIEVRITE*.

WEISSITE. *Min.* Reniform, foliated. H. above 6. G. = 2.8. Ash-gray, pearly and waxy, subtranslucent. It yields water, fuses on the edges, dissolves slowly in the fluxes, leaving silica in mic. salt. Form. $3RO, 2SiO_3 + 2(Al_2O_3, 2SiO_3)$. *Erikmatts mine*, near *Fahlun*; and *Potton*, in Lower Canada.

WELD. The stems and leaves of the *Reseda luteola*, an annual European plant, naturalized in the United States, used in the arts as a yellow dye-stuff. Its coloring power is due chiefly to a yellow principle, called by *Chevreul*—

Luteolin. Crystallizes in white spangles, soluble in alcohol, in ether, and in water. Is volatile, and sublimes in bright yellow needles. Sulphuric acid dissolves it with a yellow color. Protosulphate of iron precipitates it pale greenish yellow, turning olive-brown on exposure. Potassa, soda, ammonia, baryta, strontia, and lime change solution of luteolin to a brilliant deep yellow, and after a day all the coloring matter subsides. By exposure to air or the action of chromic acid, it is resolved into—

Luteolein. In golden-yellow laminae. Is volatile, and soluble in water, alcohol, and ether.

Chevreul also found a reddish matter in weld, which he attributes to the oxidation of the tannin.

WERNERITE. See SCAPOLITE.

WHEAT. The grain of the *Triticum hybernum*. When ground and bolted, it yields BRAN and FLOUR, the latter used as the basis of BREAD. The results of twenty-four analyses, by *Boussingault*, showed that the bran varies from 13.2 to 38.5 pr. ct., and the flour from 86.8 to 61.5 pr. ct. in different varieties; and that under the same circumstances the composition of the flour ranges as follows:—

Gluten and albumenfrom 18.2 to 25.5
Starch, sugar, gum, and water, “ 81.8 “ 74.5

Hardy's analysis of two varieties of Virginia flour (Journ. of Agric. iii. 411), gave—

	1.	2.
Starch.....	56.5	55.8
Albumen.....	0.9	1.0
Sugar.....	1.2	1.4
Gluten.....	17.0	18.5
Gum.....	1.3	1.5
Oil.....	0.8	1.0
Water.....	5.0	4.6
Soluble salts.....	0.5	0.8
Husks and bran.....	16.5	15.3
	955	

The ashes of wheat contains, according to Schmidt,—

Potassa	25.90
Soda	0.44
Lime	1.92
Magnesia	6.27
Perox. iron	1.33
Phosphoric acid	60.39
Silica	3.37

The proportions of these ingredients vary with the nature of the soil upon which the plant is grown. For the composition of wheat straw, see *ASH*. Sharpe's investigations show that the average of inorganic matter abstracted from the soil by the growing crop is one pound per acre.

As wheat flour is not unfrequently mixed with foreign matters, Donny (*Bulletin de la Société d'Encouragement*, 1847) has recommended the following modes of detecting adulterations:—

Adulteration of Flour by means of the Fecula of Potatoes. This process is founded upon the fact that a weak solution of potash, which has no visible effect upon starch, possesses, nevertheless, the property of swelling the grains of fecula, and considerably increasing their volume. The solution employed by M. Donny is made with 1 grm. 75 centigrms. of caustic potash dissolved in 100 grms. of distilled water, and consequently contains about 1.60 centigrms. of alkali. His method of proceeding is as follows:—The flour to be examined being placed upon a plate of glass, is diluted with the above solution, and inspected through the microscope; the grains of fecula may then be easily detected by their great size, compared to the starch, which is not affected by the solution. The operation may be rendered still more certain, by adding iodized water to the mixture after being well-dried from the solution, as the blue tint which will be assumed by the fecula will render the same more apparent. The difference caused by this process is so great that it is impossible to be mistaken, the grains of fecula being by the solution increased to a size about fifteen times as big as the starch.

This process is also applicable to the discovery of fecula in bread itself. For this purpose, it is only necessary to take a small quantity of the crumb, and wet it through with the solution of potash; a portion of the liquid is then squeezed out, and placed under a lens; on inspecting it, grains of fecula will be discovered by their having swelled considerably; they are, however, more difficult to distinguish, by their being misshapen by being baked; but on drying and treating them with iodine, the detection will be made with the same facility as when flour is operated upon.

Mixture of Wheat Flour with Leguminous Flour. The leguminous substances which, when pulverized, are most commonly employed for adulterating wheat flour, are peas, haricot-beans, horse-beans, &c. It may be remarked that the presence of these substances, when in any quantity, cause a smell which renders their detection easy; some of them, such as haricot-beans, will not combine in the making of bread, and cannot therefore be employed to any extent. Pease-meal will not generally mix well with

wheaten flour, and an eye somewhat experienced will easily detect the mixed flour, from its green appearance.

Donny's method is founded upon the fact that the flour of leguminous substances always contains portions of cellular tissue, which may be discovered by means of a lens or microscope. In order to expose to view this tissue (which is reticulated, and consists of hexagonal meshes, and may be easily recognised when once seen), M. Donny, after having placed a small quantity of adulterated flour on the object-bearer, dilutes it slightly with a solution of potash, of such a strength as to dissolve the fecula without touching the tissue. By this means the tissue is laid bare, and its form will be very evident; and if the leguminous flour amounts only to 3 or 4 pr. ct., it may be discovered with certainty. The only point which requires attention is, to take care not to agitate the mixture too much while on the object-bearer, for the cellular tissue might thereby be disintegrated, and the operation would thus be rendered much more difficult.

Flour of Vetches or Horse-beans. These two substances, besides possessing the peculiar characteristics possessed by leguminous substances as above mentioned, and which would be sufficient to distinguish them, have another peculiar feature, which has not yet been discovered in any other substances. This peculiar feature, which was discovered by M. Donny, has been applied by him with perfect success, in detecting the presence of these two substances in flour or other mixture. For this purpose, the flour is exposed first to the action of the vapor of nitric acid, and afterwards to that of ammonia; the result of which is, that the bean-meal will be turned a purple color, whilst the others will assume a yellowish hue. The following is the method of conducting the experiment:—1 or 2 grms. of the flour to be tested are placed in a small porcelain capsule of from 2 to 3 inches in diameter, which is slightly wetted in order to make the flour adhere to the sides, leaving the bottom empty; and in this empty space a small quantity of nitric acid is placed, so as not to be in immediate contact with the flour. The capsule is then covered with a small glass disc, and slightly heated by means of a spirit-lamp. The acid becomes vaporized, and acts upon the flour, causing it to assume a yellow tint. This tint is, however, not uniform, it being deeper at the lower part nearest the acid, and getting gradually lighter towards the top. The operation must be stopped whilst the top edge is still white, and before it has been sensibly affected by the nitric acid; the nitric acid which remains is then thrown away, and ammonia substituted; the operation is then left to itself, and a ring of a bright red color will be formed around the middle of the capsule, *i. e.* in that part where the action of the acid has neither been too strong nor too weak. As was before observed, under the same circumstances, pure wheat flour becomes yellow.

If a mixture of the two flours be operated upon, a pink tint will be produced in depth proportioned to the quantity of bean-meal. The color, which is doubtful to the naked eye, is very clearly seen under the lens or microscope, the tint being produced not by a uniform

WHEAT.

coloring of the mass, as might be imagined, but by the presence of a certain number of colored particles, consisting of grains of a deep red color, disseminated in a white or slightly yellow mass, which renders their detection very easy and certain. By this means 4 pr. ct., and even a less quantity of bean-meal, in wheaten flour, may be detected; and vetch-flour may be discovered by the same method.

Horse-bean meal is, of all leguminous substances, that which seems to mix best with wheaten flour; it gives greater tenacity to the dough, but imparts to the bread a disagreeable gray color; it has been employed some time by some of the Paris bakers, for the purpose of turning the bread, that is to say, causing it to separate easily from the peel when put into the oven, and also to give the upper crust the reddish brown color so much liked, which is caused by a portion of the flour becoming candied.

The red color which the bean-meal assumes, in consequence of the reactions above described, allows it to be detected in bread; for this purpose, a portion of the crumb is taken and macerated in cold water for two hours; it is then thrown into a sieve, and the liquor which runs from it is allowed to settle, and divides into two strata; the upper stratum is then removed and carefully evaporated, and the residuum is partially dissolved by alcohol, after which the alcoholic solution is evaporated. The residuum of this evaporation, which must be carefully spread upon the sides of the capsule, is submitted to the successive action of the vapors of nitric acid and ammonia; and under the action of these reagents, the residuum will assume the characteristic red color of bean-meal. Vetch-meal may be discovered in a similar manner.

Maize and Rice Flour. Rice flour could only be added to wheat flour in particular cases, but the flour of maize is frequently used for that purpose. Maize and rice flour may be distinguished from wheat flour by the fact of their presenting, under the microscope, angular surfaces, which are not seen in the latter; these fragments are produced by portions of the husk, which is hard in rice and maize, while it is always pulverulent and farinaceous in even the hardest kind of wheat. When any suspected flour is to be tested, M. Donny advises the gluten to be first separated by ordinary mechanical means, to collect the starch, and submit it (especially the coarser portion, which is most quickly precipitated in water) to microscopic inspection, which immediately shows the angular fragments above mentioned. It is generally advisable, for this purpose, to have a lens of small magnifying power only, which will more clearly show the difference between the fragments in question and the grains of starch.

Buck-Wheat Flour. Buck-wheat flour, like the preceding, presents angular masses, which result from the agglomeration of grains of starch set closer together; these masses may be easily detected in a mixture of buck-wheat with the best wheat flour; for this purpose, it is only necessary to separate the gluten and take the thickest part of the starch, which is to be submitted to the microscope. The general

WHITE TELLURIUM.

form of these fragments is prismatic, and similar to what is called, in commerce, "needle-starch."

These three latter kinds of flour, maize, rice, and buckwheat, are rough to the touch, the same as potato fecula; they have not that softness and unctuousity possessed by wheat flour, which property is diminished by adulteration. (*Chem. Gaz.* v. 472—476.)

WHEY. See MILK.

WHITE ANTIMONY. *Min.* Antimony bloom, Oxide of antimony, Antimonblüthe, Weissspiessglanz. Cryst. Right rhombic, with a perfect lateral cleavage, also lamellar, columnar, granular; often of the form of gray antimony. $H. = 2.5 - 3$. $G. = 5.566$. White peach-blossom red, gray, grayish yellow; lustre adamantine, shining, dull; subtransparent, opaque; sectile. Sublimes in a tube; fuses easily on coal, evolving white fumes, which coat the coal, and yields metallic antimony in the inner flame; soluble in muriatic acid, reprecipitable by water. Form. Sb_2O_3 . Crystals occur at Przibram, Bohemia; the lamellar occurs with gray and other ores of antimony.

WHITE ARSENIC. See ARSENIUM ACID.

WHITE COPPERAS. See COQUIMBITE.

WHITE GARNET. See LEUCITE.

WHITING. *Tech.* Prepared from CHALK, which, for the purpose is ground, and then washed over to separate the finer from the coarser and heavier particles.

WHITE IRON PYRITES. See IRON PYRITES.

WHITE LEAD. *Min.* Carbonate of lead, Weissbleierz, Bleierde. Cryst. Right rhombic, prismatic; frequently twinned parallel to the planes of the vertical prism, by the union of several individuals, as in Pl. IX. fig. 60, so that when the interstices are filled up, it resembles a hexagonal figure, as Pl. VIII., fig. 27; also massive, granular, compact, earthy. $H. = 3 - 3.5$. $G. = 6.465 - 6.48$. White, gray, grayish black; adamantine, metallic if dark; transparent, translucent, opaque in some of the compact and earthy; very brittle with conchoidal fracture. Decrepitates by heat, becoming yellow, coats the coal yellowish, and leaves a globule of lead; tarnishes with sulphohydrogen; dissolves in nitric acid with effervescence, reprecipitable by sulphuric acid, soluble in caustic potassa. Form. PbO, CO_2 . The compact and massive varieties contain oxide of iron and other impurities. Fine foreign localities are Leadhills, &c., Scotland; Nertchinsk, &c., Siberia; Przibram, Bohemia. In the United States, splendid specimens have been found at Washington mine, Davidson Co., North Carolina, in flat transparent crystals of more than an inch breadth; also at Austin's mines, Wythe Co. Virginia; in Madison and Jefferson Cos. Missouri, &c. &c. The most abundant locality of white lead, is that of Mine à la Motte, Madison Co. Missouri, where some thousand tons of lead have been smelted from that ore alone. From this mining tract, beautiful specimens have been obtained, associated with green carbonate of copper, and bluish black earthy cobalt. *J. C. B.*

WHITE LEAD. See Carbonate of LEAD.

WHITE PRECIPITATE. Chloramide of MERCURY.

WHITE TELLURIUM. *Min.* Aurotellu-957

WHITE VITRIOL.

WINE.

rite, Weissstellur, Tellursilberblei. Cryst. Right rhombic. Soft. $G. = 10.678$. Silver-white, inclining to yellow; metallic, opaque, rather brittle. It behaves like telluric silver, but does not smell of sulphurous acid; soluble in nitric acid, leaving gold. Form. $AgTe + 3 PbTe + 2 Au_2Te_3$. From Nagyag, Transylvania.

WHITE VITRIOL. *Min.* Cryst. Right rhombic, with a perfect cleavage parallel to shorter lateral axis. $H. = 2-2.5$. $G. = 2.036$. White; vitreous; transparent, translucent; brittle; taste astringent, metallic, nauseous. It froths by heat, gives off sulphuric acid, and coats the coal with white oxide of zinc; soluble in water, behaving like zinc-salts. It occurs in association with other ores, and is doubtless formed by the oxidation of blende.

WHITE VITRIOL. The Sulphate of ZINC.

WICHTIN. *Min.* Cryst. Right rhombic (?) cleaving into a rectangular prism. Scratches glass. Black, with flat conchoidal fracture. It contains $SiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, CaO, NaO$. From Wichity, in Finland.

WILLIAMITE. *Min.* Wilhelmit, Hebetin. Cryst. Hexagonal; also massive. $H. = 5-5.5$. $G. = 4-4.18$. Yellow, brownish; resinous; translucent, opaque; streak, white or yellowish. Behaves like siliceous zinc. Form. $3 ZnO, SiO_2$. Old Mountain in Limburg; Franklin, N. Jersey.

WILNITE. See IDOCRASE.

WINE. The fermented juice of the grape, or *Vitis vinifera*. Its general components are

alcohol, sugar, extractive and coloring matters, bitartrate of potassa, ænanthic ether, and traces of tannin, lime, gum, malic and acetic acids, and acetic ether. Wines differ in color, taste, consistence, and amount of alcohol, with the kind of grape whence obtained, and the mode of preparation. White grapes give white wines, and the color of red wines is derived from the husks of red grapes. Spirituous or generous wines are those in which the sugar is not entirely transformed. Dry wines are those from juice containing sugar and ferment in the proper proportions for mutual decomposition. Light wines are weaker, because the amount of sugar in the juice was not sufficient to generate a large amount of alcohol. These latter are liable to become acescent, if the ferment is in excess. Sparkling wines are not completely fermented, and retain carbonic acid in solution, which on escaping, produces the characteristic effervescence. Certain wines owe their astringency to the presence of tannin.

The richer and riper the grape the stronger will be the wine. The vinous odor is due to ænanthic ether and the bouquet to volatile matter generated during the fermentation; for example, acetic, butyric, or other ether. The spec. grav. ranges from 1.0627 to 1.1283.

The proportion of alcohol contained in different wines, given by Brande (Table I.) has been reduced to the standard of absolute alcohol by Fesser; and that by Fontenelle (Table II.), to the same standard by Schubarth, as in the following tables:—

TABLE I.

Name of the Wine.	Spec. grav.	100 measures contain at 60° F.		Name of the Wine.	Spec. grav.	100 measures contain 60° F.	
		Alcohol of 0.825.	Absolute alcohol.			Alcohol of 0.825.	Absolute alcohol.
Port Wine.....	0.97616	21.40	19.82	Frontignac.....	0.98452	17.79	11.84
Do.....	0.97200	25.83	23.92	Cote-Roti.....	0.98495	12.27	11.36
Mean...	0.97460	23.49	21.75	Roussillon.....	0.98005	17.24	15.96
Madeira	0.97810	19.34	17.91	Cape Madeira.....	0.97924	18.11	16.77
Do.....	0.97333	21.42	22.61	Muscat.....	0.97913	18.25	17.00
Sherry.....	0.97913	18.25	17.00	Constantia	0.97770	19.75	18.29
Do.....	0.97700	19.83	18.37	Tinto	0.98399	13.30	12.32
Bordeaux, Claret..	0.97410	12.91	11.95	Schiraz	0.98176	15.52	14.35
Do.....	0.97092	16.32	15.11	Syracuse	0.98200	15.28	14.15
Calcavella.....	0.97920	18.10	16.76	Nice.....	0.98263	14.63	13.64
Lisbon	0.97846	18.94	17.45	Tokay	0.98760	9.88	9.15
Malaga	0.98000	17.26	15.98	Raisin wine.....	0.97205	25.77	23.86
Bucellas	0.97890	18.49	17.22	Drained grape wine	0.97925	18.11	16.77
Red Madeira.....	0.97899	18.40	17.04	Lachrymæ Christi..	—	19.70	18.24
Malmsey.....	0.98090	16.40	15.91	Currant wine.....	0.97696	20.55	19.03
Marsala.....	0.98190	15.26	14.31	Gooseberry wine...	0.98550	11.84	10.96
Do.....	0.98000	17.26	15.98	Elder wine	}	0.98760	9.87 9.14
Champagne (rose)	0.98608	11.30	10.46	Cider			
Do. (white)	0.98450	12.80	11.84	Perry	}	0.99116	6.80 6.30
Burgundy.....	0.98300	14.53	13.34	Brown stout.....			
Do.....	0.98540	11.95	11.06	Ale.....	0.98873	8.88	8.00
White Hermitage..	0.97990	17.43	16.14	Porter.....	—	4.20	3.89
Red do.....	0.98495	12.32	11.40	Rum.....	0.93494	53.68	49.71
Hock.....	0.98290	14.37	13.31	Hollands	0.93855	51.60	47.77
Do.....	0.98873	8.88	8.00	Scotch whisky.....	—	54.32	50.20
Vin de Grave.....	0.98450	12.80	11.84	Irish whisky.....	—	53.90	49.91

TABLE II.

Name of the Wine.	Absolute alcohol.	Name of the Wine.	Absolute alcohol.	Name of the Wine.	Absolute alcohol.
<i>Roussillon (Eastern Pyrenees.)</i>		Sejeau 8 yrs. old	8-635	Montpellier, 5 yrs. old	7-413
Rive-salts 18 yrs. old	9-156	Narbonne 8 " "	8-379	Lunel 8 " "	7-564
Banyuls 18 " "	9-223	Lezignan 10 " "	8-173	Frontignan 5 " "	7-098
Collyouvre 15 " "	9-080	Mirepeisset 10 " "	8-589	Red Hermitage 4 " "	5-848
Salces 10 " "	8-580	Carcassonne 8 " "	7-190	White do. 4 " "	7-056
<i>Department of the Aude.</i>		<i>Department of l'Herault.</i>		Burgundy 4 " "	6-195
Fitou and Leucaté		Nissau 9 yrs. old	7-896	Grave 3 " "	5-838
10 yrs. old	8-568	Beziers 8 " "	7-728	Champagne (sparkling) do. white do.	5-880
Lapalme 10 " "	8-790	Montagnac 10 " "	8-108	Do. rose	5-145
		Mèze 10 " "	7-812	Bordeaux	4-956
				Toulouse	5-027

Adulteration of Wines. Great fraud is not unfrequently practiced in the "doctoring" of wines. Strength is imparted by the addition of alcohol, acidity corrected by the use of litharge, astringency conferred by alum, bark or rhatany, flavor by essential oil or ambergris, and color heightened by the use of color stuffs. Lead is detected by the aid of sulphuretted hydrogen.

Tests for Coloring Substances in Wines. Jacob found that basic acetate of lead on the one hand, and sulphate of alumina with carbonate of ammonia on the other, suffice for the detection and discrimination of the various coloring materials employed for coloring red wine:—

	Sulphate of alumina and carb. of ammonia.	Basic acetate of lead.
Ordinary red wine.....	Grayish precipitate.....	Bluish gray precipitate.
Logwood.....	Dark violet precip.....	Blue precip.
Brazil wood.....	Rose-red precip.....	Wine-red precip.
Wild poppy.....	Grayish precip.....	Dirty gray precip.
Recent juice of danewort } (<i>Sambucus ebulus</i>)..... }	Bright violet precip.....	Bluish gray precip. Super-natant liquid violet.
Fermented do.....	Bright violet precip.....	Beautiful grass-green precip.
Elder berries.....	Bluish gray precip.....	Dirty green precip.
Privet berries.....	Pale green precip.....	Dirty green precip.
Litmus.....	Rose-red precip.....	Bluish gray precip.

When litmus is present in small quantity it is not indicated by the above tests; the wine should then be cautiously evaporated to the consistence of an extract, a small quantity of which is dissolved in a little distilled water, and then examined. (*Journ. de Chim. Med.*, 1844, p. 92.)

Test for Alcohol. Heat the wine in open capsule, and hold a lighted taper over the surface. If spirit has been added, it inflames at a moderate heat, but otherwise does not take fire until the wine boils.

Detection of Free Sulphuric Acid. Lassaigne, Henri & Co. propose the following method for detecting this acid in wines, even to a thousandth and one-half part:—

When a piece of paper which has been touched with pure wine is dried at a gentle heat, the spotted portion is unaltered; whereas paper which has been moistened with wine, to which a very small quantity of sulphuric acid has been added, reddens, and becomes brittle and friable between the fingers when slightly rubbed before the white paper becomes at all colored.

Pure wine, to which nothing has been added, leaves by spontaneous evaporation a violet-blue spot; whereas wine to which a very small quantity of sulphuric acid has been added, (two to three thousandths), gives by drying a rose-coloured spot.

The paper most proper for the experiment is common glazed paper, containing starch or fecula. This kind of paper is well-known in commerce; and it is easy to discover it by the blue color which it assumes when moistened with an aqueous solution of iodine. (*Chem. Gaz.* vi.)

The juice of gooseberries, currants, and several other ripe fruits, yield wine by fermentation of inferior quality.

WINTERGREEN. See GAULTHERIA.

WITHAMITE. See EPIDOTE.

WITHERITE. *Min.* Carbonate of barytes, Barolite. Cryst. Right rhombic; twinned like Fig. 60, Pl. ix.; also imitative forms, especially globular with columnar, lamellar, or granular structure, and amorphous. H. = 3—3.75. G. = 4.29—4.30. White, yellowish, vitreous, subtransparent, translucent, brittle with uneven fracture. Fuses to a clear glass, which becomes enamel white on cooling; it boils on coal, becomes caustic, and sinks into the coal; soluble in dilute nitric and muriatic acids, precipitable from a very dilute solution by sulphuric acid. Form. BaO, CO₂. Obtained in considerable quantity in England, associated with galena.

WOAD. Syn. Pastel. A blue dye-stuff prepared by powdering, fermenting, and drying the leaves of the *Glastum*, (*Isatis tinctoria*), an

herbaceous plant cultivated in Europe. It is far inferior in coloring power to INDIGO. Wood substitute is made from sumac, peat, oak bark, and the stems and stalks of the hop plant. (See "Treatise on Calico Printing," p. 133.)

WOHLERITE. *Min.* Tabular, granular. $H. = 5.5$. $G. = 3.41$. Various shades of yellow, brownish, grayish; vitreous; transparent, subtranslucent; splintery fracture. By a strong heat it fuses to a yellowish glass, and shows with the fluxes the presence of manganese, iron, and silica; decomposed by heated muriatic acid, with the separation of silicic and columbic acids. Probable form. $3Zr_2O_3, Ta_2O_3 + 5(NaO, SiO_3 + 3CaO, SiO_3)$. From the islands of Langesund-Fiords, near Brevig, Norway.

WOLCHONSCOITE. See VOLKHONSKOITE.

WOLFRAM. *Min.* Tungstate of iron, Scheelate of iron and manganese. Cryst. Right rhombic, with a perfect vertical cleavage; also lamellar, columnar, granular. $H. = 5-5.5$. $G. = 7.1-7.4$. Dark grayish brownish black, submetallic, opaque, streak dark reddish brown. Fuses on coal to a magnetic globule; shows iron with borax; with mic. salt in the inner flame it becomes dark red, by adding tin, green; shows manganese with soda, and is reduced by it on coal. Decomposed in powder by hot muriatic acid leaving a yellow residue. Form. RO, WO_3 in which $RO = FeO$ and MnO ; but it is uncertain whether the tungsten is present as WO_3 or $WO_2 + WO_3$. It occurs with tin in Cornwall, Eng., Zinnwald, &c. In the United States at Lane's mine, Monroe, Conn., &c.

WOLLASTONITE. See TABULAR SPAR.

WOOD. The roots, trunk, and branches of trees, are so called in reference to their application as FUEL, or uses in the arts. Chemically considered, wood consists of LIGNIN or woody fibre, water, and sap, holding in solution albumen, salts, &c. The cellular or ligneous portion is by far the largest, and upon its greater or lesser compactness depends the distinction between *hard* and *soft* woods, and the finer the wood the greater its specific gravity. (See FUEL for table.) Density and composition of sap determine the difference between woods. The sap of the coniferæ contains resinous matter; that of the beech and birch extractive matter, and that of the oak, tannin. It, however, forms but a slight proportion of the bulk of the wood. The amount of water greatest at the time of the flow of the sap varies in different woods, as will be shown by the following table:—

100 parts of fresh cut wood from

	Water.
Hornbeam (<i>Carpinus betulus</i>) contain.....	18.6
Willow (<i>Salix caprea</i>).....	26.0
Sycamore (<i>Acer pseudoplatanus</i>).....	27.0
Mountain Ash (<i>Sorbus aucuparia</i>).....	28.3
Ash (<i>Fraxinus excelsior</i>).....	28.7
Birch (<i>Betula alba</i>).....	30.8
Wild Service Tree (<i>Crataeg. torminalis</i>)....	32.3
Oak (<i>Quercus robur</i>).....	34.7
Pedicle Oak (<i>Quercus pedunculata</i>).....	35.4
White Fir (<i>Pinus abies</i> , Duroi).....	37.1
Horse-chestnut (<i>Aesculus hippocast.</i>).....	38.2
Pine (<i>Pinus sylvestris</i> , L.).....	39.7
Red Beech (<i>Fagus sylvatica</i>).....	39.7
Alder (<i>Betula alnus</i>).....	41.6
Asp (<i>Populus tremula</i>).....	43.7

Elm (<i>Ulmus campestris</i>).....	44.5
Red Fir (<i>Pinus picea</i> , Duroi).....	45.2
Lime Tree (<i>Tilia europæa</i>).....	47.1
Italian Poplar (<i>Populus dilatata</i>).....	48.2
Larch (<i>Pinus larix</i>).....	48.6
White Poplar (<i>Populus alba</i>).....	50.6
Black Poplar (<i>Populus nigra</i>).....	51.8

The hygroscopic nature of the wood prevents the total expulsion of water by air drying, for Rumford found that air-dried woods heated to 277° lost weight, (pr. ct.), without being altered, as follows:—

Oak wood lost.....	16.64
Elm " ".....	18.20
Beech " ".....	18.56
Maple " ".....	18.63
Fir " ".....	17.53
Birch " ".....	19.38
Lime " ".....	18.79
Poplar " ".....	19.55

Late experiments have shown that wood heated in *dry* steam under pressure becomes more dense and less liable to decay.

The ash produced by incinerating wood in open vessels consists of silica, saline, and earthy matters, (see POTASSIUM and ASHES), ranging from $\frac{1}{30}$ to $\frac{1}{70}$ pr. ct. of the original wood, and varying in composition with the nature of the tree and that of the soil upon which it was grown.

The relative proportions of the proximate constituents of woods (dried at 212°) is shown by the analysis of Schödler and Peterson.

In 100 pts. they found:—

Species of Wood.	Carbon.	Hydrogen.	Oxygen.
Pure woody fibre.....	52.65	5.25	42.10
Quercus robur.....	49.43	6.07	44.50
Fraxinus excelsior....	49.36	6.075	44.57
Acer campestris.....	49.80	6.31	43.89
Fagus sylvatica.....	48.53	6.30	45.17
Betula alba.....	48.60	6.375	45.02
Ulmus campestris.....	50.19	6.425	43.39
Populus nigra.....	49.70	6.31	43.99
Tilia europæa.....	49.41	6.86	43.73
Salix fragilis.....	48.44	6.36	44.80
Pinus abies.....	49.95	6.41	43.65
Pinus picea.....	49.59	6.38	44.02
Pinus sylvestris.....	49.94	6.25	43.81
Pinus larix.....	50.11	6.31	43.58

Action of Heat upon Wood. Heated in open vessels it is transformed into carbonic oxide and acid and carbohydrogens, which pass off as gaseous products, and into ash which remains as the incombustible residuum. The *smoke* produced during the reactions consists of gaseous matter holding imperfectly burned particles in suspension, and deposits its suspended portion when coming in contact with a cool surface as Soot. If on the other hand the heating is without access of air, as in DRY DISTILLATION, the results are entirely different, a series of volatile products being formed while CHARCOAL remains as residue.

The liquid products are crude ACETIC ACID,

WOOD.

(Pyroligneous), PYROXYLIC or WOOD SPIRIT, CREASOTE, Pyrogenous resin and oil, Eupione, PICAMAR, CAPNOMOR, and the solid PITTACAL, CEDRIRET, PYROXANTHIN, PARAFFIN, NAPHTHALIN.

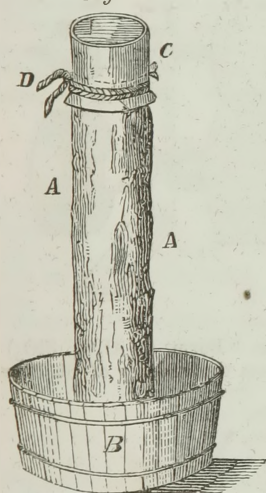
Of these components all have been described under their respective heads except—

Eupione. A limpid, colorless fluid, of fragrant odor and spec. grav. .655. Its formula is C_5H_6 . Some chemists, however, consider it isomeric with olefiant gas. The spontaneous decomposition of wood and the preventive means are given under the DECAY OF WOOD.

Coloring and Preservation of Wood. Wood may be colored in a certain way and of many desirable shades without obscuration of its natural grain, as is the case in painting it.

The usual process is by staining with a solution of color-stuff, or else by first impregnating the wood with a mordant and subsequently with a dye-stuff. Boucherie's more recent method is to saturate the wood with liquid color by means of its own capillary power. He operates as follows:—A billet of wood retaining its bark, and sawed smoothly and square at each end, is encircled at one end with a leather belt,

Fig. 94.



right position. The leather reservoir is filled with water. Fig. 94 exemplify our description.

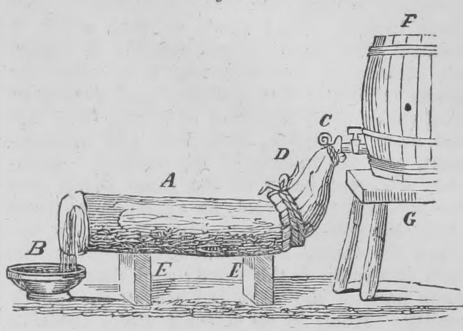
A is the piece of wood to be divested of sap; it may rest on end in a shady corner, and immediately upon the ground, unless it is desired to save the displaced liquid for analysis, or for a second transit; then the bed should be a pan or tub B. The leathern band, forming a reservoir or gutter, is seen at D, and the gutter C is kept filled with water as fast as it sinks into the wood. The first liquids which reach the tub B are generally ropy, thick, and colored, but as soon as all the sap is displaced, the water passes through limpid, and thus shows that sufficient has been employed. Now, if the wood is to be treated for the purpose of "preserving it," then after the clear water has passed through, the appropriate liquor must be allowed to percolate in a similar manner. So, likewise, the wood is treated with coloring matters. Indigo, lake, prussian blue, or any pigment diffused in water do not enter the wood acting

WOOD OPAL.

like a filter. Colored wine produces better effects.

When the tree is too long to be maintained in an upright position, the following plan is adopted, as shown by Fig. 95.

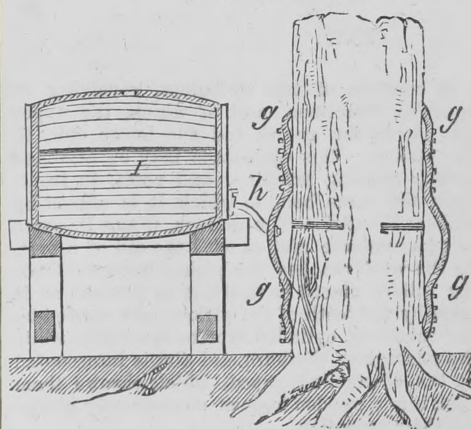
Fig. 95.



A is the tree resting upon supports E, above the tub B. The leather or rubber bag C is closely attached as before directed, and connects with an uncovered barrel F, resting upon a stand G. The greater the height of this stand the more powerfully is the liquid forced through the wood.

Metallic colors are far more durable and brilliant than those from vegetables, the latter being sensibly altered by oil polish. Boucherie has applied the foregoing process to the growing tree in manner as follows. Fig. 96 illustrates the process.

Fig. 96.



Two semicircular incisions are made through the bark of the tree, and covered with leather or lead fastened by screws in such a manner as to form tight reservoirs, as seen in section at g g g g. The barrel I is raised upon a support high enough to communicate at its base, as at h, with the protruding part of the band g. When the cock is opened the color liquid passes from the barrel to the reservoirs surrounding the incisions, and is drawn through the pores of the plant by the force of capillarity. For details, see *Journ. Franklin Institute*, 1848.

WOOD OPAL. See OPAL.

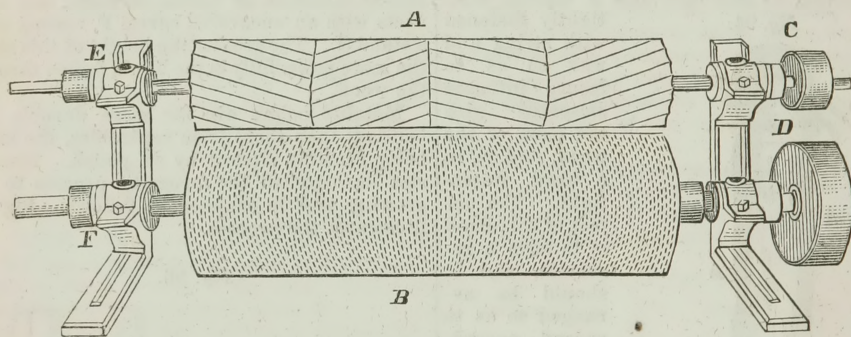
WOOD TIN. See TIN ORE.

WOODY FIBRE. See LIGNIN.

WOOL. The hairy covering of sheep, analogous in composition to feathers, and similar substances. In commerce, it is classified into long and short staple, fleece, and dead wool. The length of the filament or fibre mostly determines its value; short staple seldom exceeds three inches. Dead wool, or that which is sheared after death, is less capable of receiving color than live wool, and is in other respects inferior. The quantity and quality of wool varies with the kind of sheep, their age and state of health, their food and management, and the nature of the pasture. Moreover, different parts of the same sheep give distinct qualities of wool: for example, the finest covers the spine; the superfine, the flanks, between the thighs and shoulders. That on the neck and rump is the third; and that on the lower part of the neck and breast, the fourth quality. Wool, in its natural state, contains

more or less fatty matter, technically termed yolk, (Fr. *Suif* or *Surge*). In the fine Saxo-electoral wools of Germany, the proportion amounts to 80 per cent., and in common wools is seldom less than 20 per cent. The average is from 40 to 50 per cent. This greasy matter, which closely adheres to the fibres, consists chiefly of potassa soap, acetate of potassa, traces of carbonate of potassa, and of chloride of potassium, a little lime salt, a fatty acid, and peculiar odorant matter. Immersion in water separates most of the yolk, and that which still adheres may be removed by rinsing in fresh water, containing 25 per cent. of stale urine. Subsequent rinsing in clean water completes the operation. Dirty wools, heretofore useless, or nearly so, because of the difficulty of separating the burs and other foreign particles intermixed with the fibres, are now rendered equal in value to clean wool, and at a very slight expense, by means of Parkhurst's patent "burring machine," shown by fig. 97.

Fig. 97.



It consists of two cylinders, revolving in opposite directions, and of which, the upper one, A, is the guard, and the lower one, B, the picker. This apparatus may be attached to any carding machine, and rests, in front, upon the same bed, to which it is affixed by sockets E and F. The pulleys, C and D, serve to communicate motion with the aid of a belt. As the wool reaches the picker from the feeding rollers placed in front, it is combed as it were by the teeth of the picker, and carried by the revolving cylinder over to the cards, while the passage of the burs and dirt is intercepted by the channelled guard, which throws them back into a wooden hopper, conveniently placed for their reception.

WOORARI. *Syn.* Wooraly, Ourari, Urari. The aqueous extract of the *Strychnos toxifera*, a powerful poison, used in Guiana for envenoming the points of arrows.

WORMWOOD, OIL OF. Pungent odor and bitter taste. Sp. grav. .973 at 70°. Sp. grav. of vapor 5.300. Polarizes to the left like camphor, but less, and is isomeric with it, giving the same oil, by distillation with dry phosphoric acid. See ABSINTHIN.

WORT. See BEER.

WÖRTHITE. *Min.* Foliated. H. = 7-25. G. above 3. White, otherwise similar to kyanite. Yields water in a tube, otherwise be-

haves like kyanite. Form. $5(Al_2O_3, SiO_3) + Al_2O_3, 3HO$. From the vicinity of St. Petersburg.

X.

XANTHIC ACID. The bisulphocarbonate of oxide of ETHYL. Form. $2CS_2 + AeO$. (*Zeise*).

XANTHIC OXIDE. See URINARY CALCULI.

XANTHITE. See IDOCRASE.

XANTHOKON. *Min.* Reniform, enclosing minute crystals. H. = 2. G. = 4.112-4.159. Dull red, clove-brown, crystals yellow on edges; powder yellow. Fuses in a closed tube before ignition, becoming lead-gray, and giving a slight sublimate of sulphuret of arsenic; in an open tube gives arsenious and sulphurous acids; on charcoal, it gives sulphurous and arsenical fumes, and leaves a globule of silver. Form. $3AgS, AsS_5 + 2(3AgS, AsS_3)$. From Himmelsfürst mine, near Freiberg.

XANTHOPENIC ACID. See NARCOTIN.

XANTHOPHYLL. *Syn.* Yellow of leaves. The coloring matter of the seared leaves of autumn.

XANTHOPHYLLITE. See CLINTONITE.

XANTHOPICRIN. *Chem.* Exists in the bark of the *Xanthoxylum Clava Herculis*. Bit-

ter, astringent, greenish yellow, crystals of neutral reaction. Soluble in alcohol.

XANTHOPROTEIC ACID. See PROTEIN.

XANTHOREA. *Syn.* Botany bay resin. The resin of the *Xanthorea hastilis*. In brittle yellow masses of balsamic odor. Soluble in ether and alcohol. Yields cinnamic and benzoic acids by action of caustic alkalis. (*Chem. Gaz.* iii. 520).

XENOLITE. See BUCHOLZITE.

XENOTIME. *Min.* Phosphate of Yttria, Ytterspath. Cryst. Quadratic, with perfect lateral cleavage. $H. = 4.25 - 5$. $G. = 4.558$. Yellowish brown; resinous; opaque; fracture uneven, splintery. Infusible; dissolves slowly in the fluxes; with boracic acid and iron it gives phosphoric iron; insoluble in acids. Form. 3 YO, PO_5 . From Lindsnæs, Norway.

XYLITE,

XYLITIC ACID. } *Chem.* A volatile liquid.

$C_{12}H_{12}O_5$. Existing in pyroxylic spirit. By the action of potassa, hydrated oxide of methyl is separated, and a crystalline potassa salt, $KO, C_{15}H_{15}O_7$, formed. An excess of potassa generates xylitic naphtha, $C_{12}H_{12}O_3$; xylitic oil, $C_{12}H_9O$, and xylitic resin C_8H_6O . (*Schweitzer*).

XYLOIDIN. See GUN COTTON.

XYLORETIN. $C_{40}H_{33}O_4$. A fossil resin found in the debris of pine trees, in the peat of Denmark. Fusible and crystallizable, but decomposed by heat. See TURF.

Y.

YANOLITE. See AXINITE.

YEAST. See BREAD and FERMENTATION.

YELLOW COPPERAS. See COQUIMBITE.

YELLOW COPPER ORE. See COPPER PYRITES.

YELLOW LEAD ORE. See MOLYBDIC LEAD.

YELLOW TELLURIUM. See WHITE TELLURIUM.

YENITE. See LIEVRITE.

YPADU. *Coca*. The leaves of the *Erythrozylon Coca*, an herb of great esteem among the Indians of Peru. (*Chem. Gaz.* i. 209.)

YTRIUM. *Chem.* Yttria was discovered in 1794, by Gadolin, but 6 other bodies were subsequently obtained from his yttria. Wöhler first obtained the metal from it. It exists in very small quantity in a few rare minerals, gadolinite, orthite, yttrocerite, &c. 1. *Yttrium*. The metal is obtained by interstratifying the dry chloride of yttrium with flat pieces of potassium, in a platinum crucible, binding on the cover with wire, heating over a spirit-lamp, and when cold dissolving out chloride of potassium by water. Iron-black scales, with metallic lustre, not oxidable at common temperatures in the air or water, but brilliantly burning to yttria, when ignited in the air, and readily dissolving in dilute acids. *Sym.* Y. Eq. formerly about 32, but now uncertain.

2. *Yttria*. YO. Impure yttria is obtained from gadolinite by solution in nitromuriatic acid, evaporation to remove silica, re-solution in acid and water, precipitation by oxalate of ammonia, which throws down oxalates of yttria, cerium, lanthanum, manganese, lime, &c. The oxalates are destroyed by heat, the oxides dissolved in a little muriatic acid, cerium and

lanthanum precipitated as double sulphates by putting in crystals of sulphate of potassa, to form a saturated solution, the filtered liquid precipitated by oxalate of potassa, the oxalate of yttria, &c. decomposed by heat, dissolved in nitric acid, fused to decompose the manganese salt, extracted by water, and the solution precipitated by pure ammonia, which throws down yttria free from lime. But Mosander has rendered it probable that there are two other metallic oxides in it, whose metals he terms *erbium* and *terbium*. The behavior of their corresponding compounds is so similar, that they have not yet been separated quantitatively, and their separate properties are not accurately known.

Yttria is a strong base; attracts carbonic acid from the air; is insoluble in potassa, soluble in carbonate of ammonia and of soda. The distinguishing characters of the three earths are the following:—Yttria (proper) is colorless, soluble in strong acids; its sulphate is colorless, crystallizable; its nitrate gives a syrup by evaporation, in which crystals form; its chloride is not volatile, but is deliquescent. Salts of terbia resemble those of yttria, but have a light, amethystine tint; its sulphate gives larger crystals; its nitrate has a light, rose-red tint, crystallizes. Erbia is yellow, but its salts are colorless.

YTTRO CERITE. *Min.* Massive, with an apparent rhombic cleavage. $H. = 4 - 5$. $G. = 3.447$. Violet-blue, inclining to gray and white, also reddish brown; vitreous, pearly, glistening; opaque; fracture uneven. It yields water in a tube; infusible alone; fuses with gypsum to a cloudy bead; behaves to the fluxes like fluor spar, but the glass is yellow in the outer flame; soluble in muriatic acid; with sulphuric it gives off fluoric acid more readily than fluor spar. Its form. is $CeF + CeF + YF$, but these fluorides are mixed together in different proportions. From Finbo and Broddbo, Sweden; and from Bolton, (?) Massachusetts.

YTTROTANTALITE. *Min.* Crystalline, lamellar, and granular. $H. = 4.5 - 5.5$. $G. = 5.395 - 5.882$. Black, brownish black, yellowish brown, greenish; opaque; vitreous, resinous, the black submetallic; streak white or gray. By a slight heat the black becomes yellow; by a high heat all becomes white, and are infusible; in mic. salt there is formed a skeleton of columbic acid, which slowly dissolves; the black gives in the inner flame a reddish, the yellow a greenish glass. Form. 3 YO, Ta_2O_3 ; in the black a portion of Ta_2O_3 is replaced by U_2O_3 , and in the black by WO_3 ; in the brown a portion of YO is replaced by CaO, and in the black by CaO, FeO. Herrman's yttröilmenite is probably the same as uranoniobite. From Ytterby, Finbo, &c., Sweden.

YTTROTITANITE. See KEILHAUTE.

Z.

ZAFFRE. See COBALT, p. 462.

ZEAL. See MAIZE.

ZEAGONITE. *Min.* $G. = 2.18 - 2.265$. In character and behavior like lime-harmotome,

but when heated to 212° it loses its water, and becomes opake. Form. $2\text{CaO}, \text{SiO}_3 + 2(\text{Al}_2\text{O}_3, \text{SiO}_3) + 9\text{HO}$. It occurs with Phillipsite, on Vesuvius.

ZEILANITE. See SPINELL.

ZEOLITE. *Min.* A name formerly given to certain needle-shaped, hydrated silicates, and now employed rather as a generic term, including many species, such as *ædelforsite*, *analcime*, *apophyllite*, *brewsterite*, *chabazite*, *epistilbite*, *harmotome*, *heulandite*, *laumontite*, *leucite*, *mesotype*, *prehnite*, *scolezite*, *stilbite*, *thomsonite*, &c.

ZERO. The term applied to that degree on the scale of a THERMOMETER which indicates the melting point of ice.

ZEUXITE. *Min.* Small prisms. $H. = 4.25$. $G. = 3.051$. Brown; vitreous, glistening; opake. Imperfectly fusible. It appears to be a silicate of lime, protoxide of iron and alumina, with water. From Huel Unity mine, Cornwall.

ZINC. *Chem. Tech.* Syn. Spelter, Spiauter, Tutenag. Oxidized zinc was known to the ancients under the name of *cadmia* (*Ger.* *Galmei*), which they employed in the making of brass. Paracelsus first obtained it among Europeans in the 16th century, but it was earlier known to the Chinese. Its most abundant ore is the sulphuret or blende, but the metal is chiefly obtained from calamine, both a carbonate and silicate. It accompanies ores of lead and copper in greater or less quantities, and is an inconvenience in working the former.

METALLURGIC TREATMENT OF ZINC-ORES.

Silesian Process. The ores are roasted in a reverberatory, similar to those for roasting copper ores. They lose carbonic acid water, and become more porous and brittle. The ore is mixed with an equal volume of coal cinder or culm ($\frac{2}{3}$ of the weight), and introduced into red-hot muffles, $\frac{1}{2}$ cwt. of roasted ore being a charge for each muffle. The muffles are carefully made of fire-clay and ground muffels, air-dried for a long time, slowly fired in a separate furnace, and introduced hot into the reducing furnace. The muffels are closed by an earthen plate in front, with two openings, through the upper one of which the neck of the muffle passes, and by the lower one, which is closed by a plate during the reduction, the muffle is cleaned, and also receives its charge. The neck terminates in a cone, which slopes downward, to allow the condensed zinc to flow down into the receiving basin. The cone has an opening opposite the neck, by which a second charge is introduced into the muffle, upon the first, when the latter has been exhausted. A single square furnace contains 10 muffels, 5 on a side, heated by a single fire. The ores generally lose about 35 pr. ct. by calcination, and the roasted ore yields, on an average, 40 pr. ct. metal. From 11 to 12 tons of coals are consumed to produce 1 ton of metal, and 33 muffels destroyed for every 50 tons of metal. Silesia produces some 7—8000 tons zinc annually.

Liege Process. The roasted ore is mixed with $\frac{1}{2}$ to $\frac{2}{3}$ its bulk of fine coke, and introduced into earthen tubes. The earthen tubes are about 3 ft. long, 4—5 inches wide, and hold some 40 lbs. as a charge. They rest on fire-brick only at the back and front, the rest being ex-

posed to the fire. One stack contains 22 such tubes, laid horizontally in rows, 4 in each of the 5 rows, and two in the uppermost. The heat from a single fire plays freely among the tubes. To the front of each earthen-ware tube, a cast-iron tube is attached, contracting from $1\frac{1}{2}$ to 1 inch diameter, in which the metal condenses, and is drawn out every two hours.

English Process. Covered crucibles are introduced into a circular furnace, like a glass furnace, arched above, and heated by a single fire-place through the diameter. They have openings in the bottom, in which is a conical tube of sheet-iron; and when the process is going forward, a long sheet-iron tube is attached to the latter. A wooden plug is fitted into the opening in the bottom of the crucible, the charge of roasted ore and coal introduced through an opening in the cover, and when a blue flame appears, the latter opening is closed. As the heat rises the plug is charred, and the vapors passing through condense in drops in the iron tube, and fall into a vessel of water below. When the tubes become choked, they are cleared by a red-hot iron rod. The consumption of coal is about 12 tons coal to 1 ton of metal.

The theory of these processes is simple. The oxide of zinc is reduced to metal by the coal with which it is mixed, and the metal being volatile, passes over as vapor, and condenses in the liquid, and then in the solid form.

Where the sulphuret of zinc is employed, it is first well roasted to oxide. It is then mixed with an equal quantity of roasted calamine, a volume of coal equal to both, and sometimes with a portion of lime. This *shliech* is treated in the same way as the roasted calamine alone.

From a desire to obtain oxide of zinc as a pigment as well as the metal, patents have been latterly taken out for the treatment of zinc-ores in furnaces, without muffle, tube, or crucible, the products of combustion being condensed in chambers adjoining the furnaces. They are yet to be tried, and their success for some time may be doubted. It is, however, very desirable that this metal should be obtained in a larger and less expensive manner.

Zinc, and its non-saline compounds.

1. *Zinc.* The commercial metal is far from being pure, as it contains from 1 to 5 pr. ct. foreign ingredients, carbon, lead, cadmium, arsenic, &c., and it is impossible to purify it by distillation, or by any other process in the metallic state. The best method is to dissolve it in pure dilute acid, to purify it in solution, then to precipitate the pure oxide or carbonate, and to distil this with purified lamp-black. To remove the carbon it may still contain, redistillation is resorted to. It is a bluish white, brilliant metal, crystalline with large laminæ, and may be obtained in 6-sided prisms. It is moderately hard, and much tougher than its crystalline structure would indicate; it may be rolled into thin sheets, and drawn into wire, but with some difficulty, and is best rolled and drawn between 200° and 300° ; at 400° it is quite brittle, and may be powdered in a mortar; spec. grav. of the cast metal 6.86, and when pure 6.9, of the common rolled metal 7.19. It fuses at about 770° , and volatilizes

at a white heat; remains unaltered in dry air, becomes dull in moist air; when ignited in the air, it burns with a brilliant, bluish white light, giving off dense white fumes, which condense in woolly flakes in the air, (philosopher's wool). It does not decompose pure water at common temperatures, or even at 212° , but it decomposes steam when ignited, and at common temperatures rapidly decomposes water containing acid, slowly alkaline water. Sym. Zn. Eq. 32.5 ($32.527 \text{ H} = 1$. $406.59 \text{ O} = 100$. *Erdmann*).

2. *Oxide of Zinc.* ZnO . Prepared by heating the metal in a crucible, and separating the lighter oxide by washing over; or by igniting the hydrate. The hydrate is made by precipitating nitrate of zinc by less potassa than is sufficient to throw it all down, and washing thoroughly. The hydrate, ZnO, HO , loses its water readily by heat, becoming the dry oxide; and this by further heat becomes yellow, and again white on cooling. The native crystalline oxide is red; see RED ZINC ORE.

Salts. The oxide is a strong base; its salts are colorless, generally soluble in water, with a disagreeable, styptic taste, and acting as an emetic. The caustic alkalis produce precipitates, soluble in their excess; carbonated alkalis also give a precipitate, but that by ammonia only is soluble in its excess; when the solution contains salammoniac, the precipitation does not take place without boiling for some time; the carbonated alkaline earths do not give precipitation in the cold, but readily by boiling; phosphate of soda gives a white precipitate, soluble in caustic alkali; yellow and red prussiate of potash give precipitates soluble in muriatic acid; sulphuretted hydrogen throws down all the zinc as sulphuret from its solution, with a feeble acid, like the acetic; a small amount from a neutral sulphate, muriate, or nitrate, and none from an acidulated solution of these three acids; sulphuretted alkalis throw down the sulphuret wholly, and it is insoluble in the precipitant, in carbonated or caustic alkali, readily soluble in strong acids, slightly in acetic. All the above precipitates are white, except the yellowish red ferridcyanide. Those salts insoluble in water, are soluble in muriatic acid, and in hot salammoniac.

3. *Sulphuret of Z.* ZnS . Occurs as the mineral *BLENDE*. Obtained by igniting the dry oxide or sulphate with sulphur, or the sulphate with charcoal, is white or yellowish, fusible at a very high heat, oxidized by roasting in the air, by the action of hot nitric, muriatic, and sulphuric acids. The hydrate thrown down by an alkaline sulphuret is white, more readily soluble in the acids, slightly in acetic, and while moist, in sulphurous acid; form. ZnS, HO . When hydrogen is passed over ignited, dry sulphate of zinc, a portion is volatilized, and there remains a yellow powder, consisting nearly of ZnO, ZnS .

4. *Phosphuret of Z.* Obtained by throwing pieces of phosphorus on fused zinc, is a lead-colored metallic mass, somewhat malleable. Carburet exists in commercial zinc, and may be obtained by distilling cyanide of zinc. Nitroboride of zinc is obtained by keeping 1 pt. fused boracic acid, and $2\frac{1}{2}$ pts. cyanide of zinc at a

white heat for some time; a white powder, insoluble in acids, in aqua regia, in caustic lye, may be heated to redness without change in hydrogen, chlorine, vapor of potassium, or chloride of mercury, heated with chloride of lead or silver, it forms chloride of zinc, and a nitroboride of the other metal.

5. *Alloys.* Zinc alloys readily with potassium and sodium, and then resembles the alloys of these metals with antimony and bismuth. It has no affinity for bismuth, and combines with some difficulty with arsenic and antimony. It unites readily with lead and tin, hardening them. It alloys with copper, see BRASS. It alloys in small quantity with iron, as when a piece of the latter is plunged into melted zinc. A coating of zinc or iron is termed galvanized iron. Zinc certainly protects iron, but is itself much more subject to corrosion, for De la Rive has shown that when it contains iron, it dissolves in acids far more rapidly than when pure, and Runge has proved, that under caustic potassa in contact with iron, it dissolves 12 times as fast as when in contact with platinum.

HALOID SALTS.

1. *Chlorine.* Chloride of Z. ZnCl . Obtained by dissolving the metal in muriatic acid, evaporating to dryness, and distilling off volatile chloride, the remainder being oxychloride; it is also obtained by distilling 1 pt. zinc filings with 2 pts. chloride of mercury, or 1 pt. oxide of zinc with 2 pts. salammoniac, or dry white vitriol with common salt. It is a whitish, waxy mass, fusible above 212° , sublimable at a red heat, very soluble in water and deliquescent; soluble in 0.35 pts. absolute alcohol, from which a combination with alcohol crystallizes. The syrupy solution, with some excess of acid, yields crystals of $\text{ZnCl} + \text{HO}$. There are several basic chlorides. When zinc is boiled with its chloride as long as hydrogen is evolved, or when the chloride is imperfectly precipitated by ammonia, a white powder separates, which is $\text{ZnCl} + 3 \text{ZnO} + 4 \text{HO}$. When the chloride is precipitated by ammonia so that a small quantity redissolves, or by the action of water on ammonia-chloride of zinc, the salt is $\text{ZnCl} + 6 \text{ZnO} + 10 \text{HO}$. When the chloride is evaporated as long as it is clear, then congealed by cooling, and water poured over it, the residue is $\text{ZnCl} + 9 \text{ZnO} + x \text{HO}$.

The chloride forms double salts with chlorides of ammonium and potassium, each crystallizing with 1 HO. The ammonium double chloride is a convenient agent for tinning or leading iron. When rubbed on the heated surface of iron, copper, &c., any oxide present forms a double chloride with that of zinc, while ammonia is set free; the melted tin or lead is then poured on, and rubbed over by a visp. Chloride of zinc unites in several proportions with ammonia.

2. *Bromine.* Bromide of Z. ZnBr . Obtained by solution of the oxide in bromohydric acid, is very soluble in water, alcohol, and ether, difficult to crystallize, fusible at a red heat, and sublimable in needles, apart from the air; heated in the air, it forms oxybromide. It forms a crystallizable salt with ammonia.

3. *Iodine.* *Iodide of Z.* ZnI . Obtained by digesting an excess of zinc with iodine in water, crystallizes with difficulty, is very soluble in water, and by heating in the air, becomes oxide of zinc, losing iodine. By precipitating its solution in water by potassa, a basic iodide falls; $\text{ZnI} + 3 \text{ZnO} + 2 \text{HO}$. Digested with iodine, it forms a brown solution of biniodide of zinc. The dry iodide, saturated with ammonia-gas, forms $\text{ZnI} + 3 \text{NH}_3$; a solution of the iodide in caustic ammonia yields crystals of $\text{ZnI} + 2 \text{NH}_3$. Iodide of zinc forms double salts with other iodides. A peculiar double salt is formed by mixing solutions of nitrate of zinc and iodide of potassium, consisting of iodide of zinc and nitrate of potassa, soluble in water, and crystallizable, insoluble in alcohol.

4. *Fluorine.* *Fluoride of Z.* ZnF . Is crystallizable, difficultly soluble in water, unless it contain excess of fluohydric acid. Fluoride of zinc and potassium, $\text{KF} + \text{ZnF}$, is a soluble, crystalline, double salt. Aluminofluoride, $\text{ZnF} + \text{Al}_2\text{F}_3$, is slowly but perfectly soluble. Boro-fluoride, $\text{ZnF} + \text{BF}_3$, is a deliquescent saline mass. The silicofluoride is very soluble, crystallizing from a strong solution with the formula $3 \text{ZnF} + 2 \text{SiF}_3 + 21 \text{HO}$.

OXYSALTS.

1. *Sulphur.* *Sulphate of Z.* The neutral salt is obtained by calcining native sulphuret, or more frequently by dissolving the metal in dilute sulphuric acid and crystallizing. In order to obtain it purer, the solution of sulphate should first be boiled with metallic zinc to separate copper, &c., then saturated with chlorine, or boiled with a little nitric acid to peroxidize iron, and gently digested with carbonate of zinc to throw down peroxide of iron. Like its isomorph, sulphate of magnesia, it crystallizes in different forms and with different quantities of water. The common salt obtained in the cold is $\text{ZnO}, \text{SO}_3 + 7 \text{HO}$, that obtained from a hot solution has 6 HO. By treating the former with absolute alcohol, or adding an excess of acid to the crystallizing solution, 2 HO remains with the salt. By boiling it with alcohol of 0.86, the salt retains 5 HO. 100 pts. of water at 32° dissolve 43.02 pts. of the salt, (calculated anhydrous), and at 212° 95.03. It is insoluble in alcohol of greater strength than 0.88. The dry salt bears a high heat without decomposition, but at a sufficiently high and long continued all the acid may be expelled. It forms basic salts, consisting of 1 eq. ZnO , SO_3 , with 1, 2, 3, 5 and 7 eqs. ZnO . The first is obtained in solution by digesting the neutral salt with oxide of zinc, and the fifth by dropping this into pure water; the two following by precipitation with potassa; the fourth by the addition of water to $\text{ZnO}, \text{SO}_3 + \text{NH}_3$. It combines with various proportions of ammonia.

Sulphite of Z. is obtained in crystals from a solution of the oxide in sulphurous acid, with the formula $\text{ZnO}, \text{SO}_2 + 2 \text{HO}$; soluble in sulphurous acid, precipitable by alcohol.

Dithionate of Z. Obtained from sulphate of zinc and dithionate of baryta, is very soluble and difficult to crystallize; form. $\text{ZnO}, \text{S}_2\text{O}_5 + 6 \text{HO}$; its solution in ammonia yields salt, $\text{ZnO}, \text{S}_2\text{O}_5 + 2 \text{NH}_3$.

Dithionite of Z. is obtained by putting metallic zinc into liquid sulphurous acid, when it forms sulphite and hyposulphite of the oxide, $\text{Zn}_2 + 3 \text{SO}_2 = \text{ZnO}, \text{S}_2\text{O}_2 + \text{ZnO}, \text{SO}_2$. The sulphite may be thrown down by alcohol, or by digesting the solution gently in a close vessel with sulphur it may be wholly converted into dithionite. By evaporating the solution to a syrupy liquid and letting it stand for some time in an open bottle, sulphuret of zinc is precipitated, and the solution contains trithionate of zinc.

2. *Nitrate of Z.* Crystallizes from a syrupy solution in prisms which are deliquescent, soluble in alcohol, and composed of $\text{ZnO}, \text{NO}_5 + 6 \text{HO}$; 3 HO may be expelled by heat. By heating it further, both water and acid pass off, and basic salts remain.

3. *Phosphate.* $2 \text{ZnO}, \text{PO}_5$. Obtained by double decomposition from the sulphate, is a white insoluble powder, which dissolves in phosphoric acid to an acid salt. The basic salt, $3 \text{ZnO}, \text{PO}_5 + 2 \text{HO}$, obtained by adding basic-phosphate of ammonia or soda to sulphate of zinc, is gelatinous, and becomes granular. Both phosphates are fusible to a clear glass. Phosphate of zinc and ammonia is obtained by adding ^cphosphate of soda, containing ammonia, to chloride of zinc; form. $3 \text{ZnO}, \text{PO}_5 + \text{NH}_3 + 3 \text{HO}$. The ^bdouble phosphate is obtained by adding ^bphosphate of soda to chloride of zinc and ammonia, containing ammonia; form. $(2 \text{ZnO}, \text{PO}_5) + 2 \text{NH}_3 + 3 \text{HO}$.

Phosphite, $2 \text{ZnO}, \text{PO}_3 + 6 \text{HO}$, is white and somewhat soluble. *Hypophosphite* is very soluble and difficult to crystallize.

4. *Perchlorate*, ZnO, ClO_7 , is obtained from perchlorate of potassa and silicofluoride of zinc; it is deliquescent, but crystallizable. *Chlorate* is similarly obtained from chlorate of potassa, or by solution of carbonate of zinc in the acid. It is very soluble in water, soluble in alcohol, and may be crystallized with the form. $\text{ZnO}, \text{ClO}_5 + 6 \text{HO}$. The *hypochlorite*, ZnO, ClO , is obtained only in solution direct from the acid, and the carbonate or hydrate of zinc.

5. *Bromate*, obtained like the chlorate, crystallizes similarly, with the formula $\text{ZnO}, \text{BrO}_5 + 6 \text{HO}$. Ammonia-bromate is obtained by dissolving bromate in ammonia, and crystallizing over caustic potassa; form. $\text{ZnO}, \text{BrO}_5 + \text{NH}_3 + 3 \text{HO}$; it is decomposed by water and alcohol, leaving oxide of zinc.

6. *Iodate* is best obtained by mixing equal equivalents of sulphate of zinc and iodate of soda in solution, evaporating to dryness, and extracting by cold water; form. $\text{ZnO}, \text{IO}_5 + 2 \text{HO}$; soluble in 114 pts. cold, 76 boiling water. Ammonia-iodate crystallizes from a solution of iodate in ammonia; form. $3 (\text{ZnO}, \text{IO}_5) + 4 \text{NH}_3$; decomposed by water, which leaves oxide of zinc.

7. *Carbonate.* It is found native as CALAMINE. When sulphate of zinc is precipitated by carbonated alkali, a mixed hydrate and carbonate of varying composition is formed; $\text{ZnO}, \text{CO}_2 + \text{ZnO} + 3 \text{HO}$ and $2 (\text{ZnO}, \text{CO}_2) + 3 \text{ZnO}, + 3 \text{HO}$, and probably others. According to Wöhler, it is obtained crystallized, when a solution of oxide of zinc in caustic potassa or soda is exposed to the air. According to Kane, a saturated solution of the oxide in caustic po-

tassa thus exposed yields a double salt, $\text{KO}, \text{CO}_2 + \text{ZnO}, \text{CO}_2$. A double carbonate with soda is obtained by boiling metallic zinc for some hours with carbonate of soda, and letting it stand for some days. An ammonia salt is obtained by adding carbonate of ammonia to a solution of chloride of zinc in ammonia, and letting it evaporate.

8. *Borate*, $\text{ZnO}, 2 \text{BO}_3$, is insoluble in water, more soluble in excess of the acid, and fusible to a yellow glass.

9. *Silicate* occurs in the mineral kingdom as SILICEOUS ZINC.

ZINC BLENDE. See BLENDE.

ZINC BLOOM. *Min.* Earthy incrustations. $\text{H.} = 2-2.5$. $\text{G.} = 3.58-3.6$. Grayish, yellowish, white, dull, and opaque. It contains water and otherwise behaves like calamine. Form. $(\text{ZnO}, \text{CO}_2 + \text{HO}) + 2 (\text{ZnO}, \text{HO})$. From Bleiberg.

ZINCPHYLLITE. See HOPEITE.

ZINKENITE. *Min.* Cryst. Hexagonal or Right rhombic; also fibrous, massive. $\text{H.} = 3-3.5$. $\text{G.} = 5.303$. Steel-gray, metallic, opaque, with uneven fracture. It decrepitates on coal, fuses, gives off fumes of antimony, and may be almost wholly volatilized; in an open tube it gives fumes which are partly volatile (antimonious acid), partly fixed (antimonite of lead); decomposed by muriatic acid with the separation of chloride of lead. Form. PbS, SbS_3 . From the antimony mine of Wolfsberg on the Hartz.

ZIRCON. *Min.* Zirconite, Hyacinth, Jargon. Cryst. Quadratic, usually the 8-hedron and its four-sided prism, but sometimes showing several dioctahedra; also granular. $\text{H.} = 7.5$. $\text{G.} = 4.45-4.75$. Brown, almost black, red, yellow, gray, white; adamantine; transparent, subtranslucent. All are infusible by heat, the colored become lighter; difficulty soluble in borax, scarcely in mic. salt; not attacked by any acids, except by oil of vitriol, probably best by bisulphate of potassa. Form. $\text{Zr}_2\text{O}_3, \text{SiO}_3$. Hyacinth is applied to the brighter and more transparent varieties; Jargon to the colorless and smoky variety from Ceylon, and Zirconite to the darker, rougher, and more opaque varieties. It occurs in the Zirconienite of Norway, and in many other places in Europe. Among American localities, Buncombe county, North Carolina, affords well-defined crystals of a half inch breadth. An impure kind of brownish red color has been found on the Schuylkill river, near Philadelphia, Penn.

ZIRCONIUM. *Chem.* Klaproth discovered zirconia in 1789, and Berzelius prepared the metal in 1824. It exists in very small quantity in zircon and a few other minerals.

1. *Zirconium*. The metal is obtained by interstratifying potassium with the double fluoride of zirconium and potassium in a short iron tube, placing it in a platinum crucible, heating it at first gently, stirring it with a wire, then to ignition, washing with cold water, digesting it at $100^\circ-120^\circ$, with a mixture of equal parts muriatic acid and water, filtering, washing with sal-ammoniac water, and then with alcohol. It is a black, metallic powder, taking fire in the air below a red heat, dissolving only in heated and strong sulphuric, muriatic, and nitromuriatic acids, readily in fluoric in the cold and violently

in nitrofluoric acid. Sym. Zr. Eq. 33.58 (839.456 $\text{O} = 100$ Berz.)

2. *Zirconia*. Zr_2O_3 . It is obtained from zircon by reducing it to the finest possible powder, mixing it with three times its weight of carbonate of soda, heating it to redness, making a hole in the centre of the mass into which a piece of caustic potassa is put, and igniting by the heat of a wind furnace for $\frac{3}{4}$ of an hour. The fused mass is dissolved in water, filtered, evaporated nearly to dryness, diluted with water, filtered from silica, and precipitated by ammonia, which throws down the hydrate of zirconia. When the mineral contains oxide of iron, it will be found with the zirconia and must be separated from it. For this purpose the hydrate is dissolved in tartaric acid, an excess of ammonia added, and then sulphide of ammonium, and in a corked flask set in a warm place to deposit sulphuret of iron. The clear solution is filtered and not washed, evaporated to dryness, and ignited in an open crucible until the zirconia appears white. Berthier's method is to precipitate the solution of iron and zirconium by a mixture of ammonia and sulphide of ammonium in excess, to let it become clear in a flask, to draw off the solution, to pour a solution of sulphurous acid into the flask, whereby sulphuret of iron is instantly dissolved with a little zirconia, and the remaining zirconia is free from iron. The zirconia in the solution is precipitated pure by boiling.

It is a white, infusible powder, insoluble in acids except strong sulphuric. The hydrate is white, voluminous, quite soluble in acids while moist, but difficultly so after drying or washing with boiling water; when heated to a certain point it phosphoresces and has then become an insoluble modification. The hydrate is insoluble in caustic alkali, soluble in carbonated, and more so in bicarbonated; it is obtained from these solutions by adding sal-ammoniac and boiling. Zirconia tends to form basic salts, some of which are soluble; they are astringent but not sweet to the taste, and are precipitated by sulphate of potassa. Sulphuret of zirconium, made by heating the two elements, forms a brown powder, insoluble in acids, except the fluoric.

3. *Haloid Salts*. By igniting a mixture of zircon or zirconia and charcoal in chlorine, chloride of zircon is formed, volatile (*Wöhler*), not volatile (*Berzelius*). A solution of the earth in muriatic acid yields hydrated crystals of chloride, or, according to Hermann, of oxychloride, $2 (\text{Zr}_2\text{Cl}_3) + \text{Zr}_2\text{O}_3 + 24 \text{HO}$. When the oxychloride is gently heated it becomes insoluble and has the composition $\text{Zr}_2\text{Cl}_3 + 2 \text{Zr}_2\text{O}_3$. The bromide, Zr_2Br_3 , is very soluble and forms granular crystals. The fluoride, Zr_2F_3 , is very soluble, and by gentle evaporation yields crystals, which by solution separates into an insoluble basic salt, and a soluble acid salt. When fluoride of zirconium is dropped in fluoride of potassium, a double salt is precipitated, $2 \text{KF} + \text{Zr}_2\text{F}_3$, and when fluoride of potassium is dropped into fluoride of zirconium, the precipitated salt is $3 \text{KF} + 2 \text{Zr}_2\text{F}_3$. Silicofluoride is soluble and crystallizable. Most of the above solutions partially decompose by boiling.

4. *Oxysalts*. Neutral sulphate, $\text{Zr}_2\text{O}_3, 3 \text{SO}_3$, is obtained by digesting zirconia with oil of

vitriol, diluted with $\frac{1}{2}$ to $\frac{1}{3}$ its weight of water, and heating gently to expel the excess of acid. It is slowly soluble in cold, rapidly in hot water, and crystallizes out of an excess of sulphuric acid. A $\frac{2}{3}$ sulphate, $2\text{Zr}_2\text{O}_3, 3\text{SO}_3 = \text{Zr}_2\text{O}_3, 3\text{SO}_3 + \text{Zr}_2\text{O}_3$, is obtained by dissolving hydrate of zirconia in a solution of the neutral salt to saturation. When this solution is evaporated to dryness, and much water added, a bibasic ($\frac{1}{3}$ neutral) salt is precipitated, and the neutral is formed in the solution. Fused bisulphate of potassa dissolves zirconia, and when a large amount of the salt is used, the whole double sulphate dissolves entirely in water; when less salt a basic sulphate of zirconia remains on adding water. The same basic salt is formed when sulphate of potassa is put into a neutral solution of zirconia, bisulphate of potassa being formed, and the basic salt of zirconia; and if the free acid be neutralized by potassa, all the zirconia may be thrown down. The basic

salt is insoluble in water and in acids, soluble in carbonate of ammonia, and contains the insoluble modification of zirconia. It may be rendered soluble by fusion or ebullition with alkali. A basic *sulphite* is obtained as a precipitate by mixing solution of chloride of zirconium and sulphite of ammonia; it is soluble in sulphite of ammonia, but by boiling the hydrated earth precipitates. The *nitrate* is soluble and forms basic salts. *Borate* and *phosphate* are insoluble. Zirconia also forms an acid and a basic *carbonate*. For *silicate*, see ZIRCON and EUDIALITE.

ZOMIDIN. One of the constituents of the extract of flesh, not precipitable by tannin or by bichloride of mercury, but by neutral and basic acetates of lead. Berzelius considers that the savour of boiled and roasted meat depends upon this component. (*Simon*, p. 39.)

ZURLITE. Is probably a mixture of several Vesuvian minerals.

APPENDIX.

TABLE I.

Dilatation of Gases for each degree Cent., from 1° to 29° (= 32° to 84·2° F.), the total expansion from 32° to 212° being from 1·000 to 1·365.

Temperature in Centigrade Degrees.	Volume of Gas.	Logarithms of Gaseous Volumes.	Difference.	Temperature in Centigrade Degrees.	Volume of Gas.	Logarithms of Gaseous Volumes.	Difference.
0°	1·00000	0·00000	—	15°	1·05475	0·02315	151
1	1·00365	0·00158	158	16	1·05840	0·02465	150
2	1·00730	0·00316	158	17	1·06205	0·02615	150
3	1·01095	0·00473	157	18	1·06570	0·02764	149
4	1·01460	0·00629	156	19	1·06935	0·02912	148
5	1·01825	0·00785	156	20	1·07300	0·03060	148
6	1·02190	0·00941	156	21	1·07665	0·03207	147
7	1·02555	0·01096	155	22	1·08030	0·03354	147
8	1·02920	0·01250	154	23	1·08395	0·03501	147
9	1·03285	0·01404	154	24	1·08760	0·03647	146
10	1·03650	0·01557	153	25	1·09125	0·03792	145
11	1·04015	0·01710	153	26	1·09490	0·03937	145
12	1·04380	0·01862	152	27	1·09855	0·04082	145
13	1·04745	0·02013	151	28	1·10220	0·04226	144
14	1·05110	0·02164	151	29	1·10585	0·04370	144

TABLE II.

Tension of Aqueous Vapor, expressed in Millimetres, for each degree Cent., from —11° to +30° (+12·2° to 86° F.).

Temperature in Centigrade Degrees.	Tension in Millimetres.	Temperature in Centigrade Degrees.	Tension in Millimetres.	Temperature in Centigrade Degrees.	Tension in Millimetres.
— 11	2·46	+ 3	6·12	+ 17	14·47
— 10	2·63	+ 4	6·52	+ 18	15·35
— 9	2·81	+ 5	6·95	+ 19	16·29
— 8	3·01	+ 6	7·40	+ 20	17·31
— 7	3·21	+ 7	7·87	+ 21	18·32
— 6	3·43	+ 8	8·38	+ 22	19·42
— 5	3·66	+ 9	8·91	+ 23	20·58
— 4	3·91	+ 10	9·48	+ 24	21·81
— 3	4·17	+ 11	10·07	+ 25	23·09
— 2	4·45	+ 12	10·71	+ 26	24·45
— 1	4·75	+ 13	11·38	+ 27	25·88
0	5·06	+ 14	12·09	+ 28	27·39
+ 1	5·39	+ 15	12·84	+ 29	29·05
+ 2	5·75	+ 16	13·63	+ 30	30·64

TABLE III.
To Calculate the Weight of given Volumes of Gases and Vapors.

Names of Gases.	Constituent or Component parts of a Vol. of the Gases.	Product of Condensation.	Specific Weight.		Absolute Weight, in Grammes, to 0° C., and 0.76 Metre, of Cubic Centimetres.									
			Found.	Calculated.	1000	2000	3000	4000	5000	6000	7000	8000	9000	
					1000	2000	3000	4000	5000	6000	7000	8000	9000	
Alcohol	$\text{CH}_3\text{O} \frac{1}{2}$	9 : 2	} 1.6183	1.60049	2.07916	4.15832	6.23748	8.31664	10.39580	12.47496	14.55412	16.63328	18.71244	
Hydrate of ethyl...	$\frac{1}{2}\text{C}_2\text{H}_5\text{O} + \frac{1}{2}\text{HO} \frac{1}{2}$	1 : 1		0.5967	0.59120	0.76801	1.53602	2.30403	3.07204	3.84005	4.60806	5.37607	6.14408	6.91209
Ammonia	$\frac{1}{2}\text{N} + \frac{3}{2}\text{H}$	2 : 1			17.78388	23.10260	46.20520	69.30780	92.41040	115.51300	138.61560	161.71820	184.82080	207.92340
Antimony	Sb	2	.....	4.54917	5.90972	11.81944	17.72916	23.63888	29.54860	35.45832	41.36804	47.27776	53.18748	
Antimonietted hyd.	$\frac{1}{4}\text{Sb} + \frac{3}{4}\text{H}$	7 : 4	.....	10.36536	13.46538	26.93076	40.39614	53.86152	67.32690	80.79228	94.25766	107.72304	121.18842	
Arsenic	As	2	10.65	10.36536	13.46538	26.93076	40.39614	53.86152	67.32690	80.79228	94.25766	107.72304	121.18842	
Arsenuretted hyd.	$\frac{1}{4}\text{As} + \frac{3}{4}\text{H}$	7 : 4	2.695	2.69454	3.50041	7.00082	10.50123	14.00164	17.50205	21.00246	24.50287	28.00328	31.50369	
Arsenic acid	As + 3 O	3 : 1	13.85	13.67316	17.76247	35.52494	53.28741	71.04988	88.81235	106.57482	124.33729	142.09976	159.86223	
Atmospheric air .....	.....	.....	1.000	1.00000	1.299075	2.598150	3.897225	5.196300	6.495375	7.794450	9.093525	10.392600	11.691675	
Boron	B	1	.....	1.59334	1.94776	3.89552	5.84328	7.79104	9.73880	11.68656	13.63432	15.58208	17.52984	
Bromine	Br	1	5.54	5.39837	7.00639	14.01278	21.01917	28.02556	35.03195	42.03834	49.04473	56.05112	63.05751	
Carbon	C	1	.....	0.84279	1.09485	2.18970	3.28455	4.37940	5.47425	6.56910	7.66395	8.75880	9.85365	
Carbonic acid	$\frac{1}{2}\text{C} + \text{O}$	3 : 2	1.524	1.52400	1.97978	3.95956	5.93934	7.91912	9.89890	11.87868	13.85846	15.83824	17.81802	
Carbonic oxide	$\frac{2}{3}\text{C} + \frac{1}{3}\text{O}$	5 : 6	0.9409	0.97269	1.26360	2.52720	3.79080	5.05440	6.31800	7.58160	8.84520	10.10880	11.37240	
Carburet of sulph.	$\frac{1}{2}\text{S} + \text{C}$	7 : 4	2.6447	2.63944	3.42883	6.85766	10.28649	13.71532	17.14415	20.57298	24.00181	27.43064	30.85947	
Chloride of antim.	$\frac{1}{4}\text{Sb} + \frac{3}{4}\text{Cl}$	7 : 4	7.8	8.10647	10.53090	21.06180	31.59270	42.12360	52.65450	63.18540	73.71630	84.24720	94.77810	
Chloride of arsenic	$\frac{1}{4}\text{As} + \frac{3}{4}\text{Cl}$	7 : 4	6.3006	6.25183	8.12161	16.24322	24.36483	32.48644	40.60805	48.72966	56.85127	64.97288	73.09449	
Chloride of boron	$\frac{1}{4}\text{B} + \frac{3}{4}\text{Cl}$	7 : 4	8.942	4.08532	5.24220	10.48440	15.72660	20.96880	26.21100	31.45320	36.69540	41.93760	47.17980	
Chloride of phos.	$\frac{1}{6}\text{P} + \frac{5}{6}\text{Cl}$	11 : 6	4.85	4.78814	6.22016	12.44032	18.66048	24.88064	31.10080	37.32096	43.54112	49.76128	55.98144	
Chloride of silica	$\frac{1}{3}\text{Si} + \frac{2}{3}\text{Cl}$	7 : 3	5.939	5.90049	7.66517	15.33034	22.99551	30.66068	38.32585	45.99102	53.65619	61.32136	68.98653	
Chloride of sulph.	$\frac{1}{2}\text{S} + \text{Cl}$	4 : 3	4.70	4.65838	6.05158	12.10316	18.15474	24.20632	30.25790	36.30948	42.36106	48.41264	54.46422	
Chloride of tin	$\frac{1}{2}\text{Sn} + \text{Cl}$	5 : 2	9.1997	8.93433	11.60639	23.21278	34.81917	46.42556	58.03195	69.63834	81.24473	92.85112	104.45751	
Chloride of titan	$\frac{1}{2}\text{Ti} + \frac{3}{2}\text{Cl}$	5 : 2	6.836	6.54488	8.51528	17.03056	25.54584	34.06112	42.57640	51.09168	59.60696	68.12224	76.63752	
Chlorine	Cl	1	2.47	2.44033	3.17017	6.34034	9.51051	12.68068	15.85085	19.02102	22.19119	25.36136	28.53153	
Chromium	Cr	1	.....	3.87916	5.09392	10.07864	15.11796	20.15798	25.19660	30.23592	35.27524	40.31456	45.35388	
Cyanogen	C + N	2 : 1	1.8064	1.81879	2.36275	4.72550	7.08825	9.45100	11.81375	14.17650	16.53925	18.90200	21.26475	
Ether	$\text{C}_2\text{H}_5\text{O} \frac{1}{2}$	15 : 2	} 2.586	2.58088	3.35276	6.70552	10.05828	13.41104	16.76380	20.11656	23.46932	26.82208	30.17484	
Hydrate of ethyl.	$2\text{CH}_3 + \text{HO} \frac{1}{2}$	3 : 1			0.98039	1.27360	2.54720	3.82080	5.09440	6.36800	7.64160	8.91520	10.18880	11.46240
Oxide of ethyl	$\text{C}_2\text{H}_5 + \text{O} \frac{1}{2}$	3 : 2			1.28894	1.67443	3.34886	5.02329	6.69772	8.37215	10.04658	11.72101	13.39544	15.06987
Ether. olefant gas.	$\text{C}_2\text{H}_5 + \text{CH}_2$	3 : 1	0.9852	1.28894	1.67443	3.34886	5.02329	6.69772	8.37215	10.04658	11.72101	13.39544	15.06987	
Fluorine	F	1	.....	1.28894	1.67443	3.34886	5.02329	6.69772	8.37215	10.04658	11.72101	13.39544	15.06987	
Gas of marshes	$\frac{1}{2}\text{C} + 2\text{H}$	5 : 2	0.556	0.55900	0.72619	1.45238	2.17857	2.90476	3.63095	4.35714	5.08338	5.80952	6.53571	

APPENDIX.

Hydriodic acid	$\frac{1}{2}I + \frac{1}{2}H$	1 : 1	4 : 44	4 : 83495	5 : 69639	11 : 39278	17 : 08917	22 : 78556	28 : 48195	34 : 17834	39 : 87473	45 : 57112	51 : 26751
Hydrobromic acid..	$\frac{1}{2}Br + \frac{1}{2}H$	1 : 1	.....	2 : 73107	3 : 54788	10 : 64364	14 : 19152	17 : 73940	17 : 73940	21 : 28728	24 : 83516	28 : 38304	31 : 93092
Hydrochloric acid..	$\frac{1}{2}Cl + \frac{1}{2}H$	1 : 1	1 : 2474	1 : 25407	1 : 62977	3 : 25954	4 : 88931	6 : 51908	8 : 14885	9 : 77862	11 : 40839	13 : 03816	14 : 66793
Hydrocyanic acid ..	$\frac{1}{2}CN + \frac{1}{2}H$	1 : 1	0 : 9476	0 : 94379	1 : 22606	2 : 45212	3 : 67818	4 : 90424	6 : 13030	7 : 35636	8 : 58242	9 : 80848	11 : 03454
Hydrofluobora- cic acid.....	$\frac{1}{3}B + \frac{2}{3}F$	7 : 4	2 : 3124	2 : 30824	2 : 9858	5 : 99716	8 : 99574	11 : 99432	14 : 99290	17 : 99148	20 : 99006	23 : 98864	26 : 98722
Hydrofluoric acid..	$\frac{1}{3}F + \frac{2}{3}H$	1 : 1	.....	0 : 67887	0 : 88190	1 : 76380	2 : 64570	3 : 52760	4 : 40950	5 : 29140	6 : 17330	7 : 05520	7 : 93710
Hydrofluosilic acid	$\frac{1}{3}Si + \frac{2}{3}F$	7 : 8	3 : 600	3 : 59771	4 : 67369	9 : 34738	14 : 02107	18 : 69476	23 : 36845	28 : 04214	32 : 71583	37 : 38952	42 : 06321
Hydrogen	$\frac{1}{2}H$	1	0 : 0688	0 : 06880	0 : 0838	0 : 17876	0 : 26814	0 : 35752	0 : 44690	0 : 53628	0 : 62566	0 : 71504	0 : 80442
Iodine	$\frac{1}{2}I$	1	8 : 716	8 : 70111	11 : 30340	22 : 60680	33 : 91020	45 : 21360	56 : 51700	67 : 82040	79 : 12380	90 : 42720	101 : 73060
Ioduret of arsenic..	$\frac{1}{2}As + \frac{1}{2}I$	7 : 4	16 : 1	15 : 64300	20 : 32144	40 : 64288	60 : 96432	81 : 28576	101 : 60720	121 : 92864	142 : 25008	162 : 57152	182 : 89296
Ioduret of mercury	$\frac{1}{2}Hg + \frac{1}{2}I$	2 : 1	16 : 2	15 : 67959	20 : 36897	40 : 73794	61 : 10691	81 : 16728	101 : 84485	122 : 21382	142 : 58279	162 : 94517	183 : 32073
Mercury	$\frac{1}{2}Hg$	$\frac{1}{2}$	7 : 03	6 : 97848	9 : 06557	18 : 13114	27 : 19671	36 : 26228	45 : 32785	54 : 39342	63 : 45899	72 : 52456	81 : 59013
Nitric oxide	$\frac{1}{2}N + \frac{1}{2}O$	1 : 1	1 : 03880	1 : 03930	1 : 35013	2 : 70026	4 : 05039	5 : 40052	6 : 75065	8 : 10078	9 : 45091	10 : 80104	12 : 15117
Nitrogen	$\frac{1}{2}N$	1	0 : 976	1 : 26790	2 : 53580	3 : 80370	5 : 07160	6 : 33950	7 : 60740	8 : 87530	10 : 14320	11 : 41110	12 : 67900
Nitrous oxide	$\frac{1}{2}N + \frac{1}{2}O$	3 : 2	1 : 5204	1 : 52730	1 : 98408	3 : 96816	5 : 95224	7 : 93632	9 : 92040	11 : 90448	13 : 88856	15 : 87264	17 : 85672
Oxychlor. chrom....	$Cr\frac{1}{2} + OCl$	5 : 2	5 : 9	5 : 48251	7 : 12219	14 : 24438	21 : 36657	28 : 48876	35 : 61095	42 : 73314	49 : 85533	56 : 97752	64 : 09971
Oxygen	$\frac{1}{2}O$	1	1 : 026	.....	1 : 43236	2 : 86472	4 : 29708	5 : 72944	7 : 16180	8 : 59416	10 : 02632	11 : 45888	12 : 89124
Pechlor. of phos..	$\frac{1}{2}P + \frac{1}{2}Cl$	7 : 4	4 : 875	4 : 74109	6 : 16007	12 : 32014	18 : 48021	24 : 64028	30 : 80035	36 : 96042	43 : 12049	49 : 28056	55 : 44063
Phosgen gas	$C\frac{1}{2}O\frac{1}{2} + Cl$	2 : 1	.....	3 : 41302	4 : 43377	8 : 86754	13 : 30131	17 : 73508	22 : 16885	26 : 60262	31 : 03639	35 : 47016	39 : 90393
Phosphorus	$\frac{1}{2}P$	2	4 : 58	4 : 32562	5 : 61930	11 : 23860	16 : 85790	22 : 47720	28 : 09650	33 : 71380	39 : 33510	44 : 95440	50 : 57370
Phosphuretted hydrogen (the two kinds).....	$\frac{1}{4}P + \frac{3}{4}H$	7 : 4	1 : 151	1 : 18460	1 : 53889	3 : 07778	4 : 61667	6 : 15556	7 : 69445	9 : 23334	10 : 77223	12 : 31112	13 : 85001
Proto-br. of merc..	$Hg + Br$	2 : 1	12 : 16	12 : 37185	16 : 07196	32 : 14392	48 : 21388	64 : 28784	80 : 35980	96 : 43176	112 : 50372	128 : 57568	144 : 64764
Proto-chlor. merc..	$Hg + Cl$	2 : 1	9 : 8	9 : 41881	12 : 23574	24 : 47148	36 : 70722	48 : 94296	61 : 17870	73 : 41444	85 : 65018	97 : 88592	110 : 12166
Quadrihydrocar....	$2C + 4H$	6 : 1	1 : 8	1 : 96078	2 : 54722	5 : 09444	7 : 64166	10 : 18888	12 : 73610	15 : 28332	17 : 83054	20 : 37776	22 : 92498
Selenious acid	$Se + O$	2 : 1	4 : 03	3 : 82923	4 : 97446	9 : 94892	14 : 92338	19 : 89784	24 : 87230	29 : 84676	34 : 82122	39 : 79568	44 : 77014
Selenium	Se	$\frac{1}{2}$	.....	2 : 72663	3 : 54210	7 : 08420	10 : 62650	14 : 16840	17 : 71050	21 : 25260	24 : 79470	28 : 33680	31 : 87890
Silicium	Si	1	.....	3 : 05949	4 : 32483	8 : 64966	12 : 97449	17 : 30932	21 : 63415	25 : 95898	30 : 28381	34 : 60864	38 : 93347
Sub-brom. of merc..	$Hg + \frac{1}{2}Br$	3 : 2	10 : 11	9 : 67516	12 : 56876	25 : 13752	37 : 70628	50 : 27504	62 : 84380	75 : 41256	87 : 98132	100 : 55008	113 : 11884
Sub-chlor. of merc.	$Hg + \frac{1}{2}Cl$	3 : 2	8 : 35	8 : 19864	10 : 65065	21 : 30130	31 : 95195	42 : 60260	53 : 25325	63 : 90390	74 : 55455	85 : 20520	95 : 85585
Sulphur	$\frac{1}{2}S$	3	6 : 90	6 : 65415	8 : 64423	17 : 28846	25 : 93269	34 : 57692	43 : 22115	51 : 86338	60 : 50961	69 : 15384	77 : 79807
Sulphuretted hydr..	$\frac{1}{2}S + H$	7 : 6	1 : 1192	1 : 17782	1 : 53008	3 : 06016	4 : 59024	6 : 12032	7 : 65040	9 : 18048	10 : 71056	12 : 24064	13 : 77072
Sulphuret of merc.	$\frac{1}{2}Hg + \frac{1}{2}S$	7 : 9	5 : 95	5 : 39167	7 : 00418	14 : 00836	21 : 01254	28 : 01672	35 : 02090	42 : 02508	49 : 02926	56 : 03344	63 : 03762
Sulphurous acid....	$\frac{1}{2}S + O$	7 : 6	2 : 247	2 : 21162	2 : 87306	5 : 74612	8 : 61918	11 : 49224	14 : 36330	17 : 23886	20 : 11142	22 : 98448	25 : 85754
Sulphuric acid.....	$\frac{1}{2}S + O$	10 : 6	3 : 01	2 : 76292	3 : 58924	7 : 17848	10 : 76772	14 : 33696	17 : 94620	21 : 53544	25 : 12468	28 : 71392	32 : 30316
Tin	Sn	3 : 2	.....	8 : 10735	10 : 53210	21 : 06420	31 : 59630	42 : 12840	52 : 66050	63 : 19260	73 : 72470	84 : 25680	94 : 78890
Titanium	Ti	1	.....	3 : 34844	4 : 34988	9 : 94892	14 : 92338	19 : 89784	24 : 87230	29 : 84676	34 : 82122	39 : 79568	44 : 77014
Water	$H + \frac{1}{2}O$	3 : 2	0 : 6235	0 : 62010	0 : 80556	1 : 61113	2 : 41608	3 : 22224	4 : 02780	4 : 83336	5 : 63892	6 : 44448	7 : 25004

APPENDIX.

TABLE IV.

Barometer Scale in Millimetres and Inches.

Mm.	In.	Mm.	In.	Mm.	In.
700	= 27·560	730	= 28·741	760	= 29·922
701	= 27·590	731	= 28·780	761	= 29·961
702	= 27·638	732	= 28·819	762	= 30·000
703	= 27·678	733	= 28·859	763	= 30·040
704	= 27·717	734	= 28·898	764	= 30·079
705	= 27·756	735	= 28·938	765	= 30·119
706	= 27·795	736	= 28·977	766	= 30·158
707	= 27·835	737	= 29·016	767	= 30·197
708	= 27·876	738	= 29·056	768	= 30·237
709	= 27·914	739	= 29·095	769	= 30·276
710	= 27·953	740	= 29·134	770	= 30·315
711	= 27·992	741	= 29·174	771	= 30·355
712	= 28·032	742	= 29·213	772	= 30·384
713	= 28·071	743	= 29·252	773	= 30·434
714	= 28·111	744	= 29·292	774	= 30·473
715	= 28·150	745	= 29·331	775	= 30·512
716	= 28·189	746	= 29·371	776	= 30·552
717	= 28·229	747	= 29·410	777	= 30·591
718	= 28·268	748	= 29·449	778	= 30·631
719	= 28·308	749	= 29·489	779	= 30·670
720	= 28·347	750	= 29·528	780	= 30·709
721	= 28·386	751	= 29·567	781	= 30·749
722	= 28·426	752	= 29·607	782	= 30·788
723	= 28·465	753	= 29·646	783	= 30·827
724	= 28·504	754	= 29·685	784	= 30·867
725	= 28·543	755	= 29·725	785	= 30·906
726	= 28·583	756	= 29·764	786	= 30·945
727	= 28·622	757	= 29·804	787	= 30·985
728	= 28·661	758	= 29·843	788	= 31·024
729	= 28·701	759	= 29·882	789	= 31·063

28 inches = 711·187 millimetres.

29 “ = 735·587 “

30 “ = 761·986 “

31 “ = 787·386 “

1 millimetre = 0·03937 inch.

·1 “ = 0·00394 “

·01 “ = 0·00039 “

1 inch = 25·39954 millimetres.

·1 “ = 2·53995 “

·01 “ = 0·25400 “

·001 “ = 0·02540 “

TABLE V.

For converting French Decimal Measures and Weights into English Measures and Weights.

A. MEASURES OF LENGTH.

	1	2	3	4	5	6	7	8	9
METRE.									
English Yards.....	1.09363	2.18727	3.28090	4.37453	5.46816	6.56180	7.65543	8.74906	9.84270
“ Feet.....	3.28090	6.56180	9.84270	13.12360	16.40450	19.68539	22.96629	26.24719	29.52809
“ Inches.....	39.37080	78.74158	118.11236	157.48315	196.85394	236.22473	275.59552	314.96630	354.33709
DECIMETRE.									
Feet.....	0.32809	0.65618	0.98427	1.31236	1.64045	1.96854	2.29663	2.62472	2.95281
Inches.....	3.93708	7.87416	11.81124	15.74832	19.68539	23.62247	27.55955	31.49663	35.43371
CENTIMETRE.									
Inches.....	0.39371	0.78742	1.18112	1.57483	1.96854	2.36225	2.75596	3.14966	3.54337
MILLIMETRE.									
Inches.....	0.03937	0.07874	0.11811	0.15748	0.19685	0.23623	0.27560	0.31497	0.35434

B. MEASURES OF CAPACITY.

	1	2	3	4	5	6	7	8	9
CUBIC CENTIMETRE.									
Cubic Inch.....	0.06103	0.12205	0.18308	0.24411	0.30514	0.36616	0.42719	0.48822	0.54924
LITRE.									
English Imperial Gallons.....	0.22017	0.44033	0.66050	0.88066	1.10083	1.32100	1.54116	1.76133	1.98149
“ “ Quarts.....	0.88066	1.76133	2.64199	3.52266	4.40332	5.28398	6.16465	7.04531	7.92598
“ “ Pints.....	1.76133	2.52266	5.28399	7.04531	8.80664	10.56797	12.32930	14.09062	15.85195
LITRE.									
Wine Gallon, (231 c. i.).....	0.26459	0.52918	0.79378	1.05837	1.32296	1.58755	1.85213	2.11673	2.38132
STERE.									
Gallons.....	220.16643	440.33287	660.49930	880.66574	1100.83217	1320.99860	1541.16504	1761.33147	1981.49791

TABLE V—Continued.

C. WEIGHTS.

	1	2	3	4	5	6	7	8	9
KILOGRAMME.									
Cwt.	0.01970	0.03939	0.05909	0.07879	0.09848	0.11818	0.13788	0.15758	0.17727
lb. (avoirdupois.)	2.20486	4.40971	6.61457	8.81943	11.02428	13.22914	15.43400	17.63886	19.84371
KILOGRAMME.									
pound (troy)	2.67951	5.35903	8.03854	10.71805	13.39757	16.07708	18.75659	21.43610	24.11562
GRAMME.									
Grains	15.44242	30.88484	46.32726	61.76968	77.21210	92.65352	108.09694	123.53936	138.98178
DECIGRAMME.									
Grains	1.54424	3.08848	4.63273	6.17697	7.72121	9.26535	10.80969	12.35394	13.89818
CENTIGRAMME.									
Grains	0.15442	0.30885	0.46327	0.61770	0.77212	0.92654	1.08097	1.23539	1.38982
MILLIGRAMME.									
Grains	0.01544	0.03089	0.04633	0.06177	0.07721	0.09265	0.10810	0.12354	0.13898

These tables are arranged on the same plan as the Analytical Tables in Rose's "*Analytical Chemistry*," and other works of similar character. One example may suffice to illustrate the mode of using them. Let it be required to find how many grains are equal to 87.435 grammes :—

By Column 8 line 4 of Table C, we find : 80 grammes = 1235.3936 grains.
 " 7 " 4 " " 7 " = 108.0969 "
 " 4 " 5 " " 4 " = 6.1770 "
 " 3 " 6 " " 0.03 " = 0.4633 "
 " 5 " 7 " " 0.005 " = 0.0772 "
 87.435 grammes = 1350.2080 grains.

Plate I.

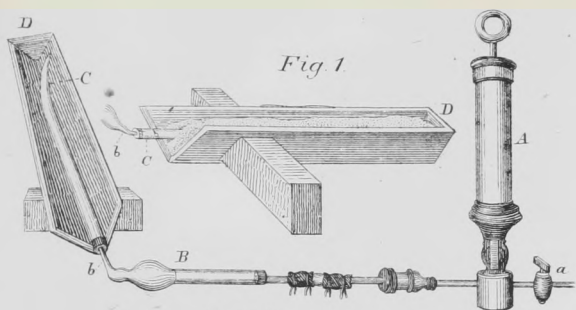


Fig. 1



Fig. 6



Fig. 7

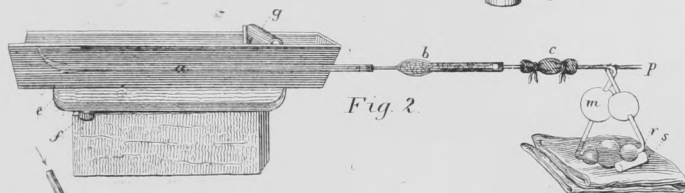


Fig. 2

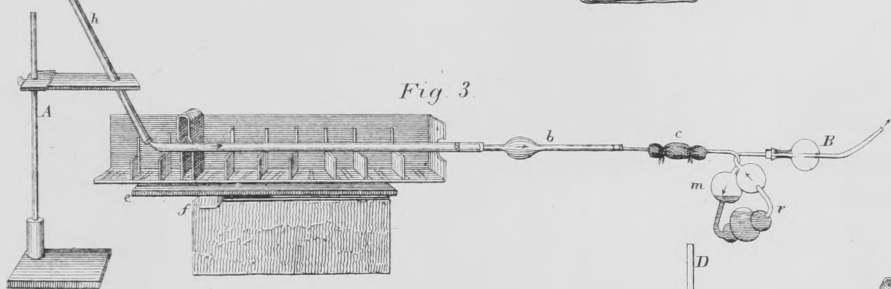


Fig. 3

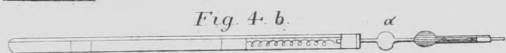


Fig. 4. b

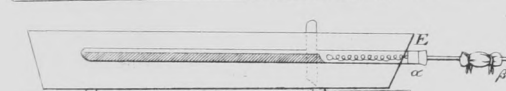


Fig. 4. a

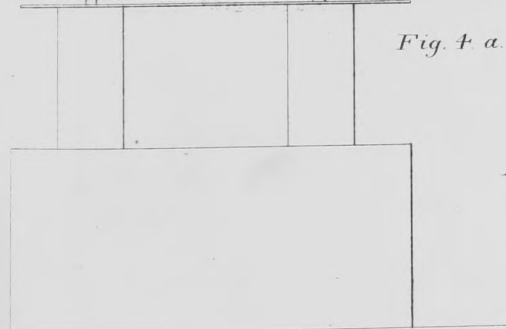


Fig. 5

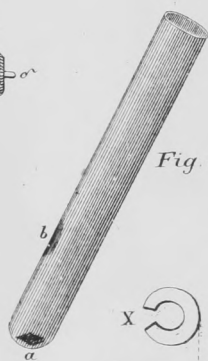


Fig. 8

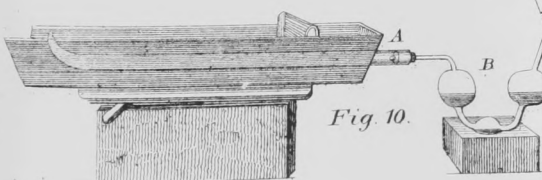
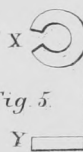


Fig. 10

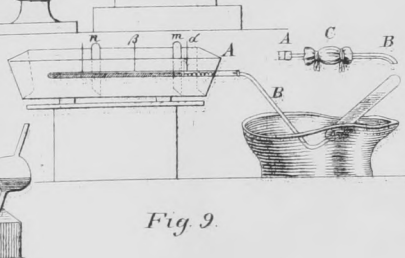


Fig. 9

Plate II

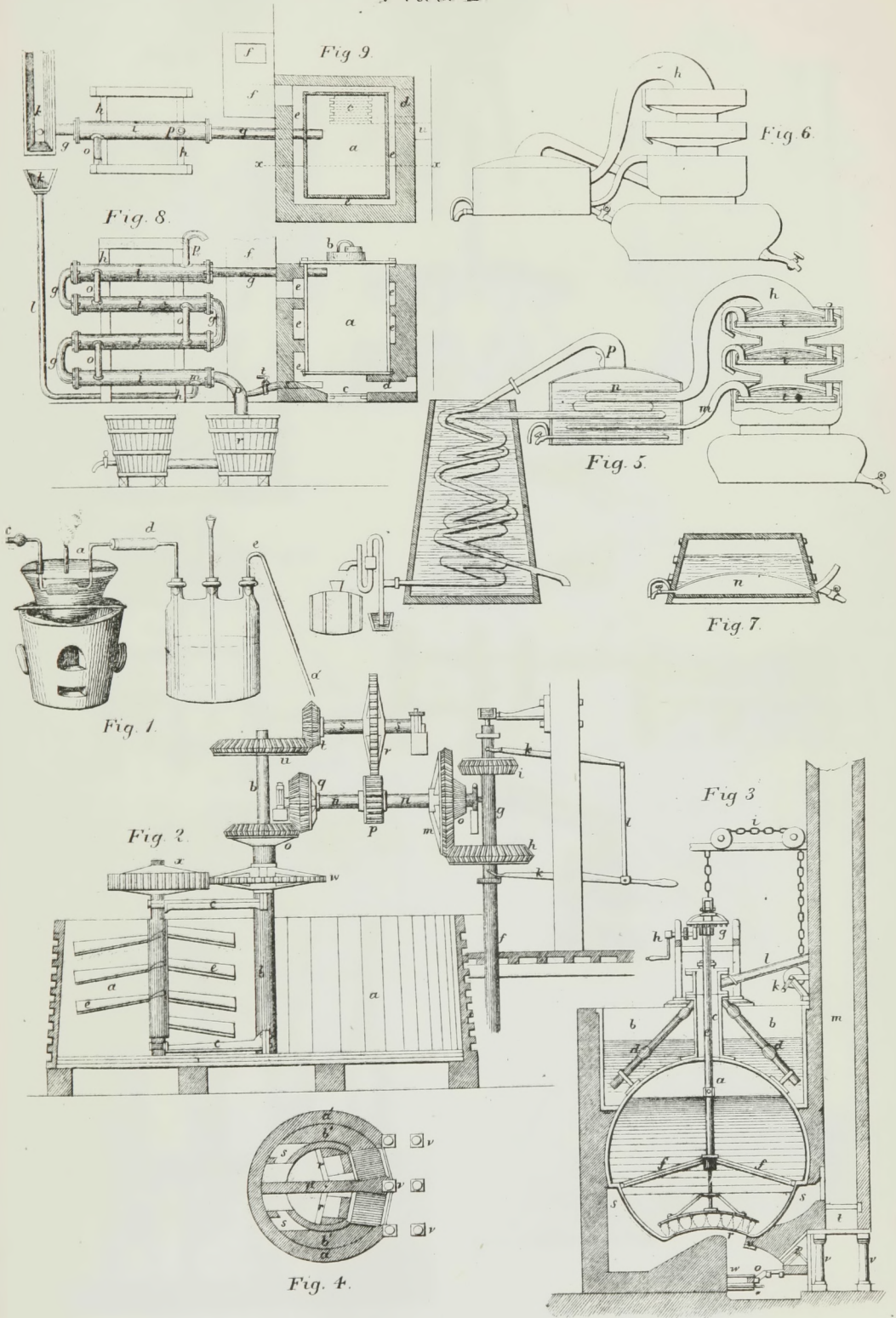


Plate III.

Fig. 3.

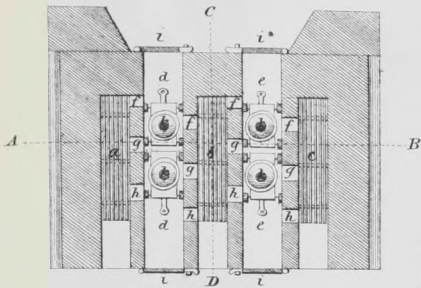


Fig. 1.

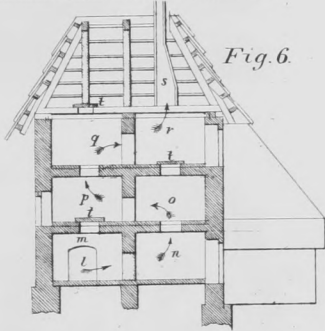
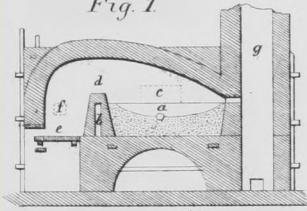


Fig. 6.

Fig. 9.

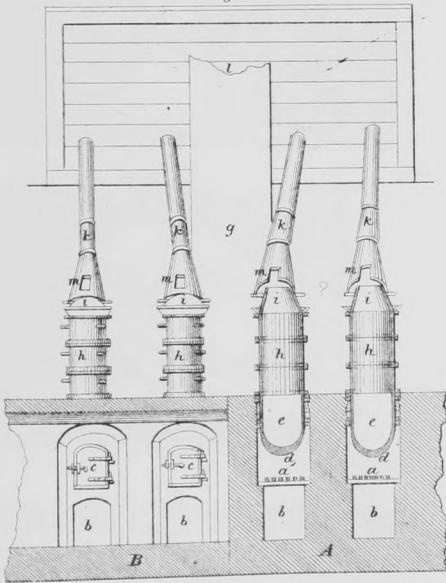


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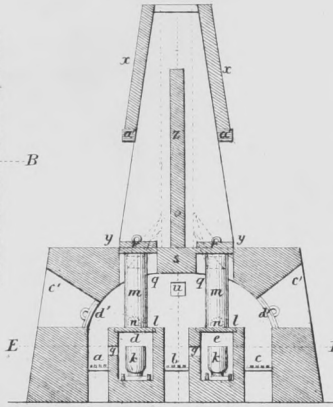


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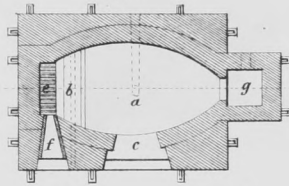


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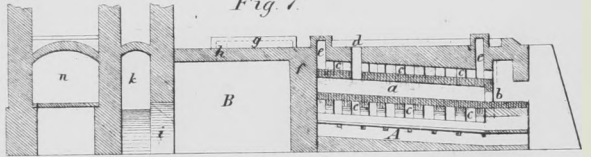


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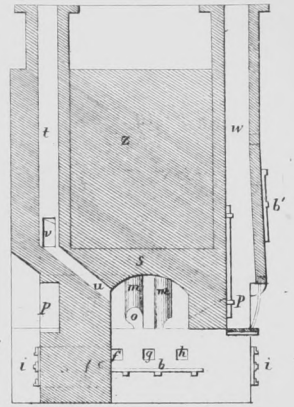


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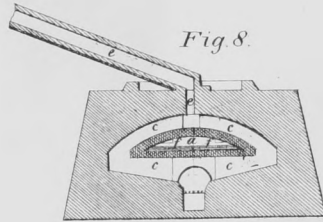


Fig. 10.

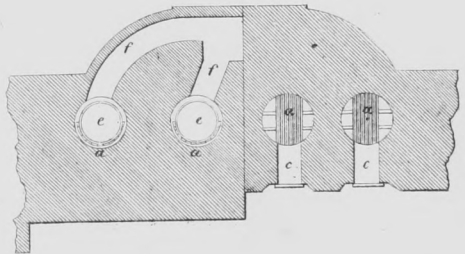


Plate IV.

Fig 6.

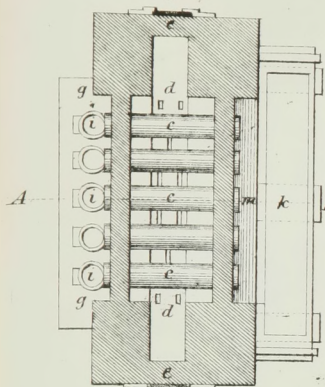


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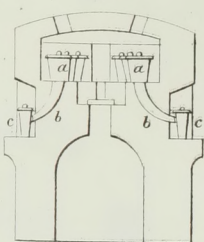


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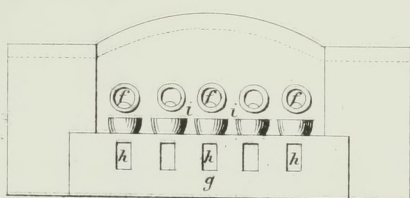


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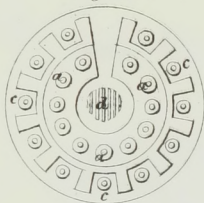


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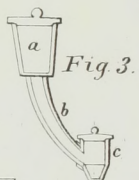
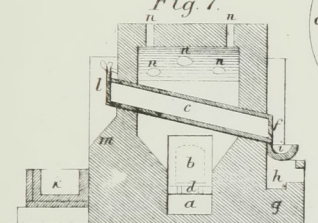


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Fig. 9.

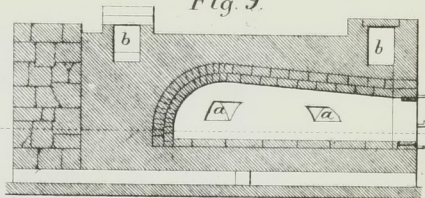


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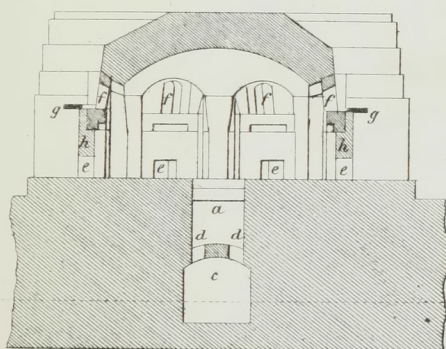


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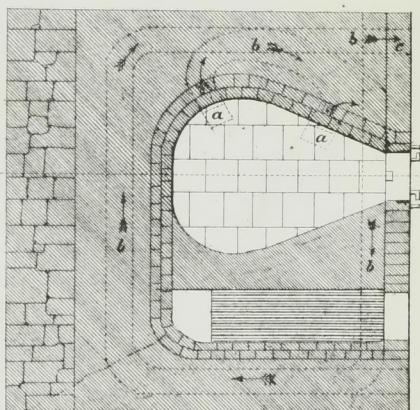


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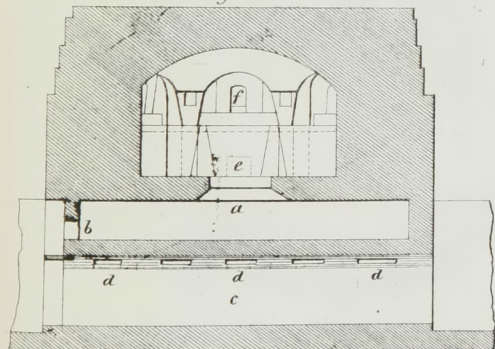


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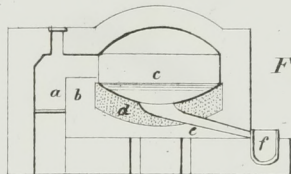


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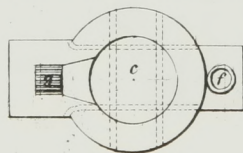


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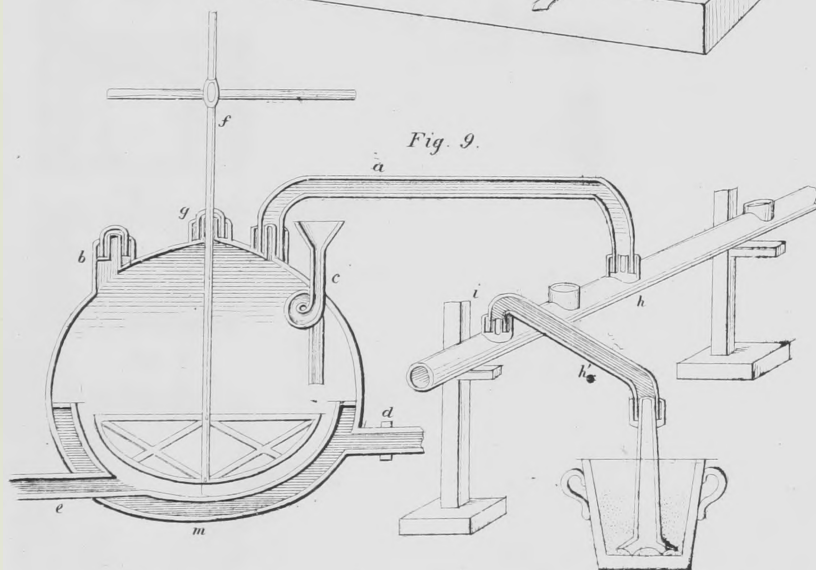
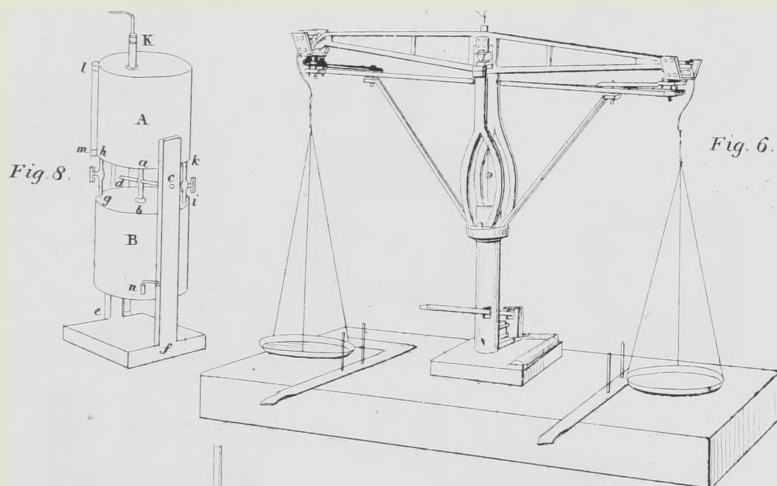
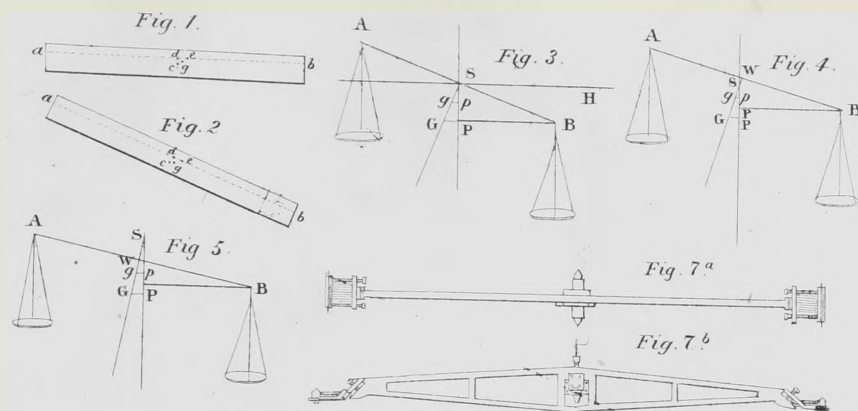
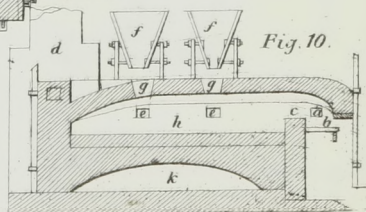
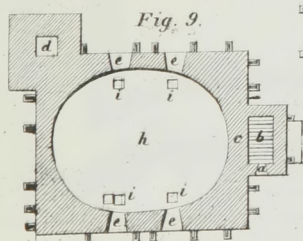
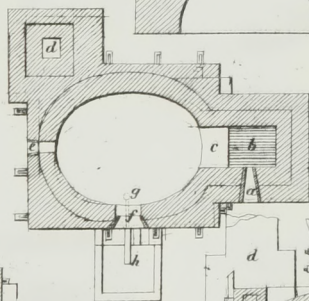
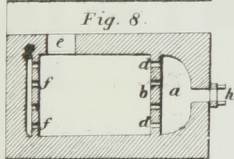
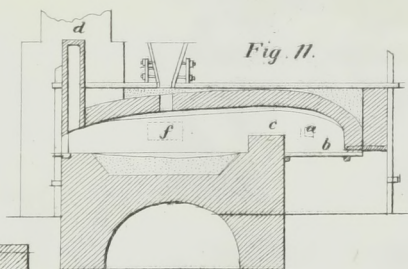
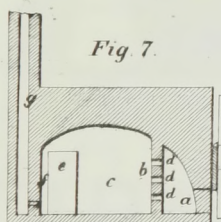
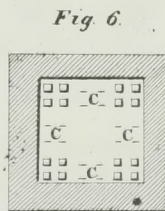
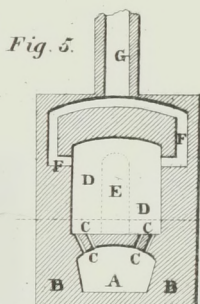
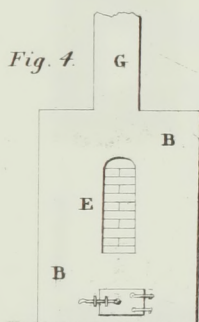
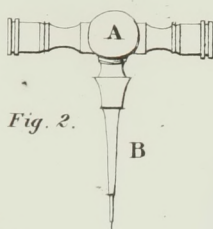
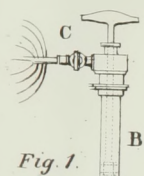
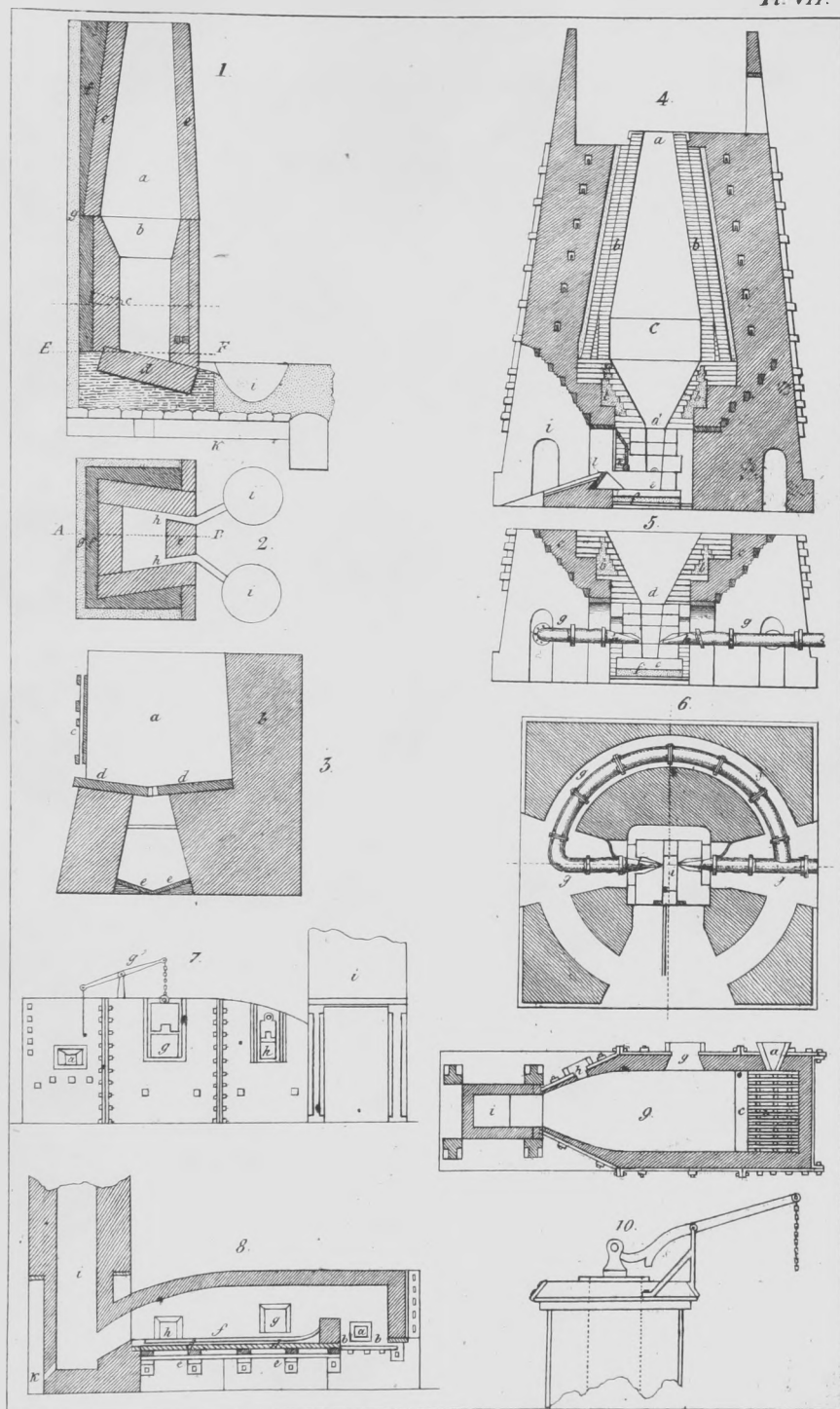
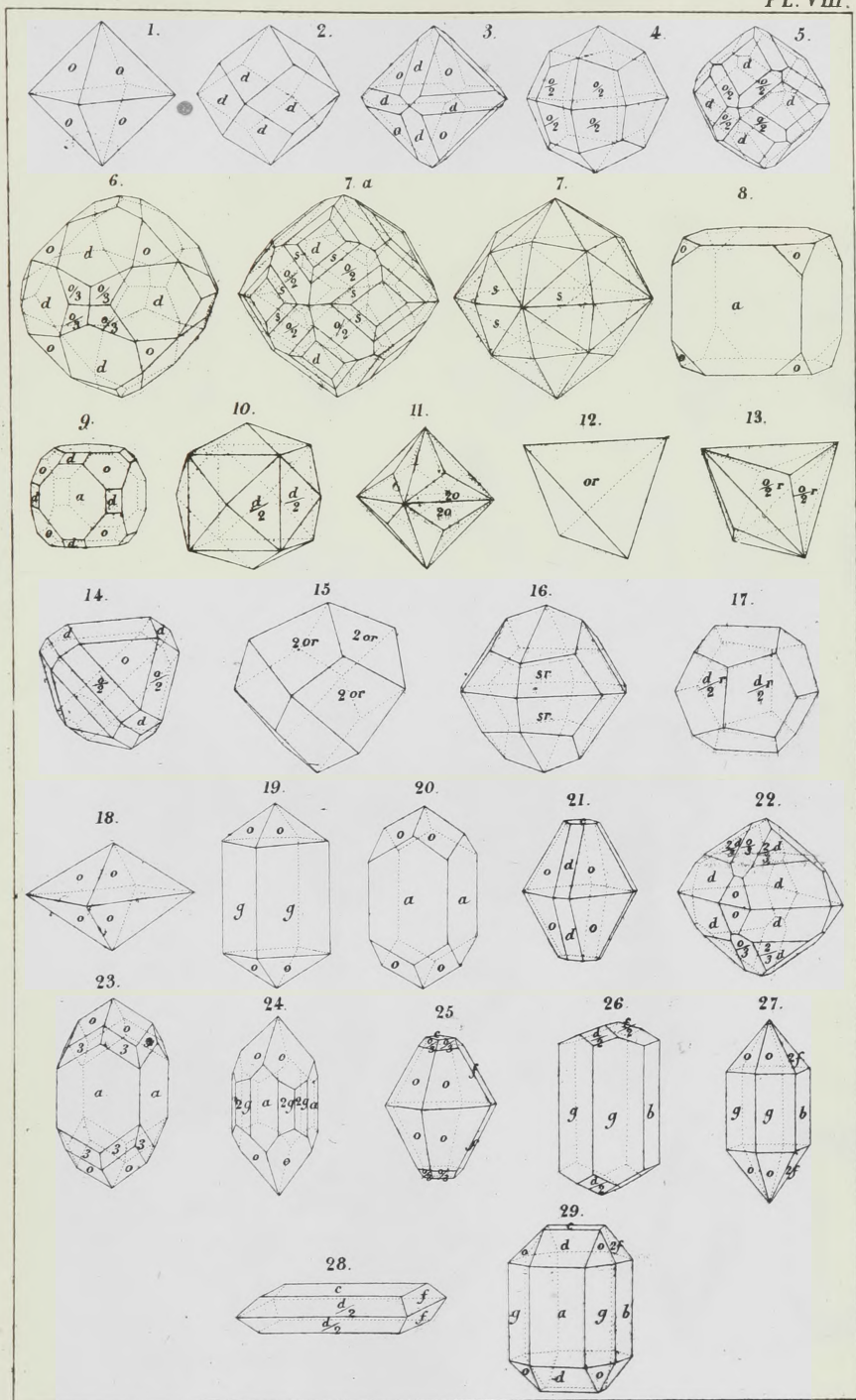


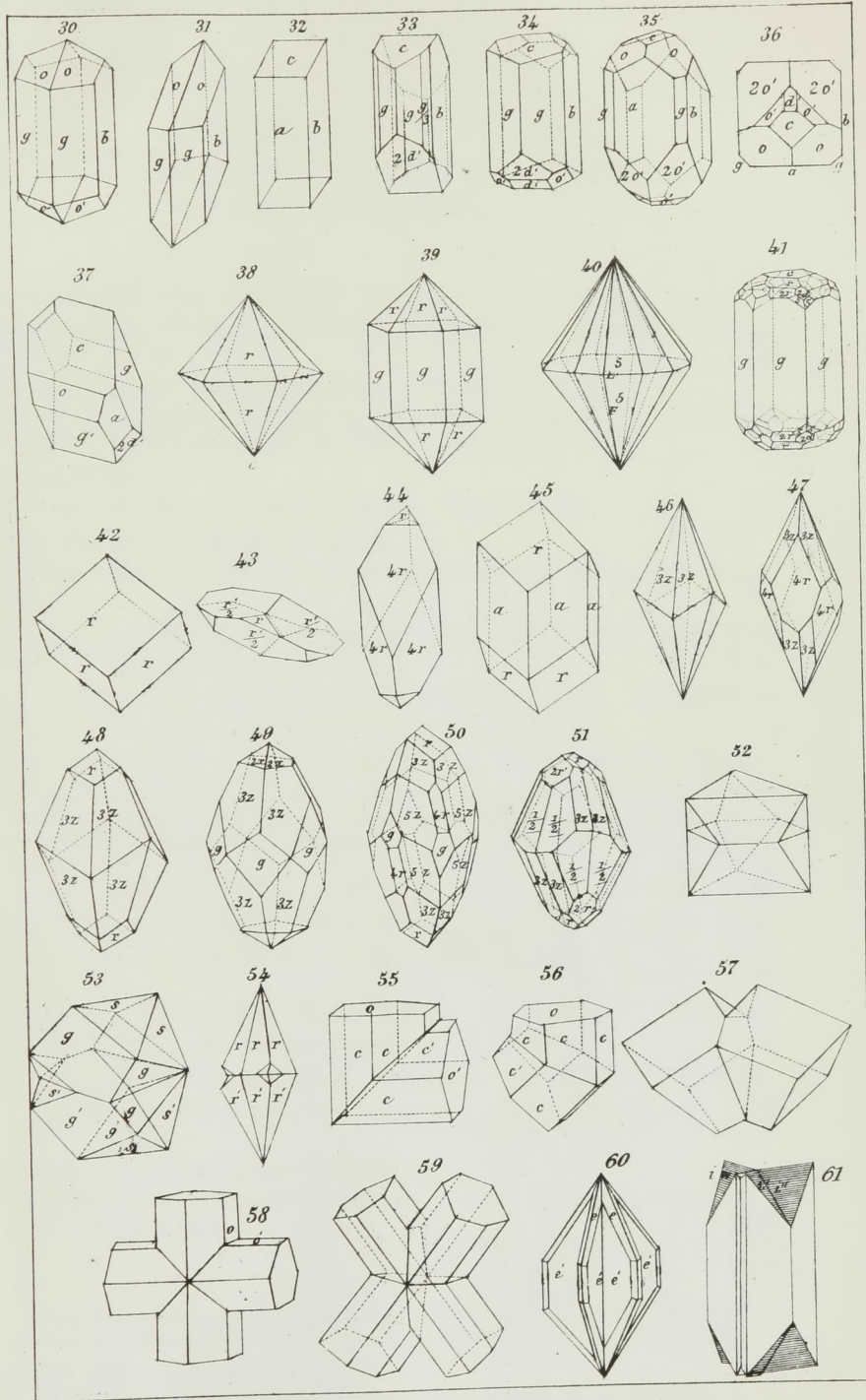
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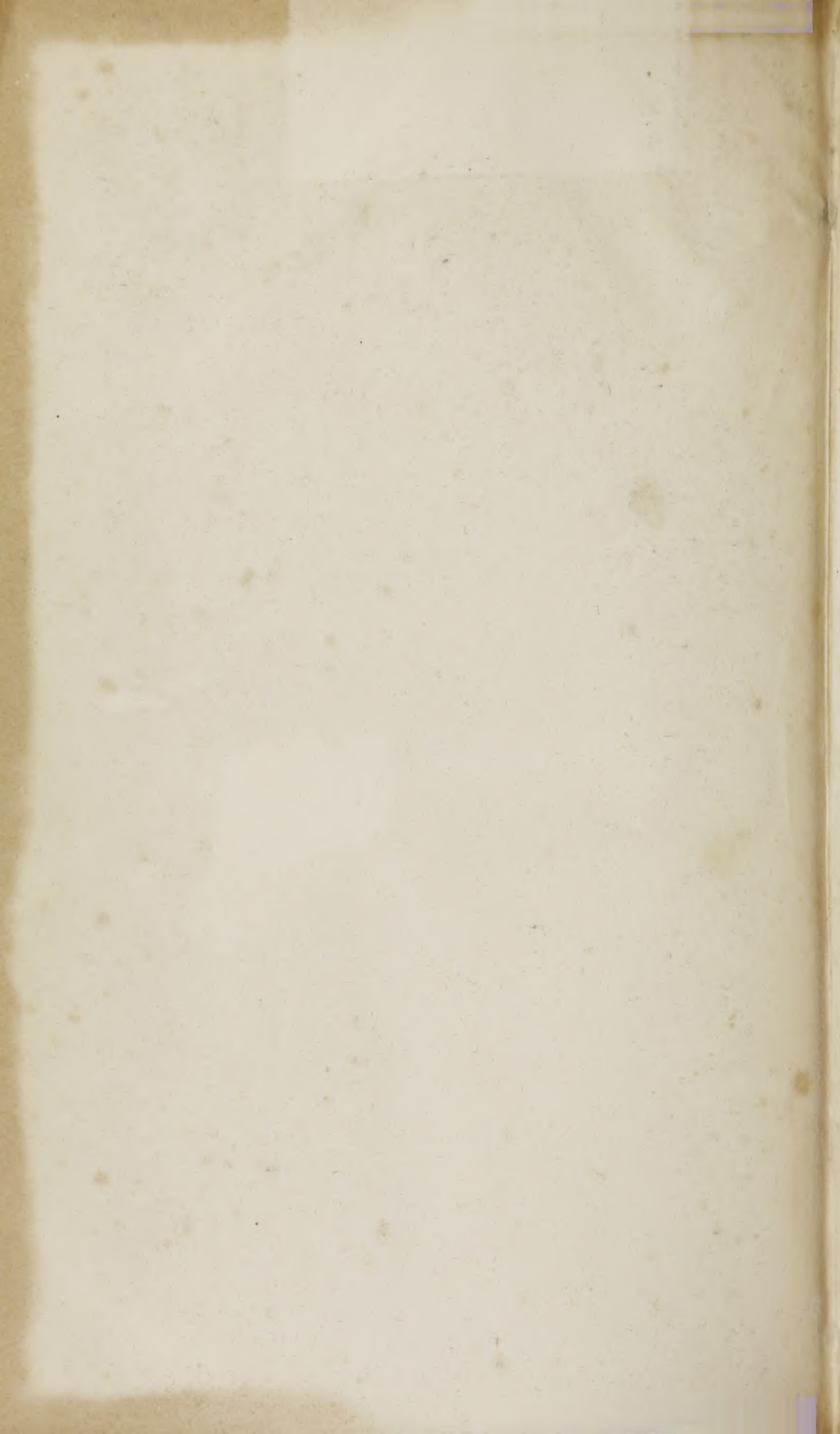
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